KIRKALDY'S EXPERIMENTAL INQUIRY

INTO THE PROPERTIES OF

ESSEN AND YORKSHIRE WROUGHT-IRON PLATES.

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RESULTS

OF

AN EXPERIMENTAL INQUIRY

INTO THE

RELATIVE PROPERTIES OF WROUGHT-IRON PLATES

MANUFACTURED AT

ESSEN, RHENISH PRUSSIA, AND YORKSHIRE, ENGLAND.

BY

DAVID KIRKALDY.

LONDON:

TESTING AND EXPERIMENTING WORKS, 99 SOUTHWARK STREET, S.E.

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PRELIMINARY REMARKS.

HAVING been informed that it was desired to ascertain, by means of a series of experiments, the relative merits of Wrought-Iron Plates, manufactured by FRIED. KRUPP, at the Essen Works, Rhenish Prussia, and of those manufactured in Yorkshire, England, I requested to be provided with pieces not less than four feet by three feet, and of the following thicknesses—as being those most generally in use for boiler making, namely—three-eight inch, half-inch, and five-eight inch; that three pieces of each thickness be sent of those made at Essen, and one of each thickness from six Yorkshire firms, every piece to have the Maker's Brand.

I accordingly received nine pieces branded "Krupp ⁂," and three pieces each, having the following brands:—"Low Moor," "Bowling, Yorkshire," "Farnley," "Taylor's • Leeds • Yorkshire," "Cooper & Co., Leeds • Yorkshire," "Monk Bridge, Yorkshire." Total number of plates being twenty-seven.

The position of ten specimens were marked out on each plate, and the distinguishing numbers were all carefully stamped on each before commencing to cut off any of the specimens, so as to prevent the possibility of any subsequent confusion. None of the specimens were sheared off, but all were cut in a slotting machine, so as not to affect the texture of the iron.

The ten specimens from each plate were for the following tests, namely—Four specimens for subjecting to Pulling stress, two being cut out lengthway, and two crossway of the plate, one of each being tested in the same condition as received, or unannealed, the others after being heated and annealed. Two for Bulging stress, one for testing unannealed, the other annealed. Four for Bending stress, one lengthway and one crossway of the plate for being tested cold, and two when heated to a "cherry red." Those specimens that were annealed were heated to a "blood red," and all at the same time in a large air furnace, they were placed on a circular table, which was rotated so as to insure all the specimens being uniformly heated, and they were not removed until the furnace was cold.

The pieces of plate remaining, after the foregoing tests were made, were subsequently prepared for ascertaining the differences between holes that were Drilled and those that were Punched, thereby adding materially to the completeness of the series.

Every specimen was measured, tested, and the results fully recorded by myself, personally, and in a series of tabulated reports I have given, in the most convenient form I could devise, the numerical results. The whole of the three hundred and twenty-four specimens are carefully preserved, and may be seen in my Museum of Fractures. I shall now proceed to analyze and direct attention to the principal facts elicited during this inquiry.

REPORTS A, B, C, D.

To ascertain the Elastic and Ultimate Strength, Softness, and Ductility under Pulling Stress.

The one-hundred-and-eight specimens were all accurately prepared to the form shown by the accompanying woodcuts, having the shoulders at each end carefully turned to insure a fair and direct pull when being tested. Length of each specimen, extreme, 17·5 inches; between heads, 12·0 inches; and for ascertaining the rates of extension, 10·0 inches, Breadth, extreme, 4·5 inches; central portion, 2·00 inches. The results of each individual plate are given in Reports A, B, C, and a general summary of the mean results of each group in Report D. We will proceed to consider—

Firstly. As regards the Elastic stress, or the elastic limit, or the amount of load at which the elasticity of the specimen becomes impaired. The nine Essen plates give a total mean of 26,199 lbs. per square inch of sectional area when tested lengthway of the plates, and in the same condition as received, and 24,577 lbs. after being annealed, when tested crossway of the plate, as received, 25,655 lbs., and 24,144 lbs. when annealed, mean of the whole being 25,144 lbs. The eighteen Yorkshire plates yielded under the same conditions, and in same order, 27,910, 27,005, 27,883, 27,111, mean of the whole being 27,477 lbs. The difference of 2,333 lbs. per square inch, or 9·2 per cent., being caused by the additional hardness of the Yorkshire plates.

Secondly. As regards the Ultimate stress, or the greatest load sustained by the specimen previous to being fractured, and taking the results in the same order, we find that the nine Essen plates yielded the following averages: 50,924, 46,760, 48,718, 45,711, mean of the whole being 48,028 lbs. per square inch. The eighteen Yorkshire plates, 47,915, 45,204, 45,659, 43,282, mean of the whole being 45,515 lbs. The difference in favour of Essen being 2,513 lbs. per square inch, or 5·5 per cent.

Thirdly. As regards the relative Softness of the plates, as shown by the Contraction of area at Fracture, the Essen plates yielded the following averages: 39·6, 43·7, 24·8, 27·0, mean of the whole being 33·8 per cent. of the original area of the specimen. The Yorkshire plates 20·6, 22·2, 14·7, 16·9, mean of the whole 18·6; difference in favour of Essen being 15·2 per cent.

Fourthly. As regards the Ultimate stress per square inch of the specimens' Fractured area: Essen 85,144, 83,759, 65,359, 63,907, total mean 74,542 lbs.; Yorkshire 61,140, 59,428, 54,110, 52,823, total mean 56,875 lbs.; difference in favour of Essen being 17,667 lbs., or 31·1 per cent.

Fifthly. As regards the relative Ductility as indicated by the ultimate Extension of the specimens when broken: Essen 25·4, 28·2, 17·4, 19·7, total mean 22·7 per cent. of their original length; Yorkshire 16·7, 18·4, 11·2, 12·8, total mean 14·8 per cent.; difference in favour of Essen being 7·9 per cent.

REPORT E.

To Ascertain the Effects produced by Drilled Holes and by Punched Holes under Pulling Stress.

The accompanying woodcuts represent the shape of the fifty-four specimens, with two rows of rivet-holes in the central portion, two-and-a-half inches apart between their centres, and the pitch of the four holes across the plate being two inches. The one row being to exhibit the elongation of the holes after the plate was pulled asunder, the other that without being fractured. The punched holes were conical as usual, being larger on the exit than on the entrance side of the plate. Those drilled were all made exactly to the smaller size, and thus suitable for the same sized rivet. Diameter of holes ·85 inch × 4 = 3·40 inches, or 42·5 per cent. of the width of the specimen; 8·00 inches being the total width of the central portion. In the columns headed "Size of the Specimen" it will be observed that the space occupied by the rivet-holes is *not* deducted as customary in making calculations on riveted-joints, and that the gross and not the net area is stated. My reasons for doing so will presently appear.

In preceding reports, and in the remarks thereupon, the Stress is given in lbs. per Square-inch of the specimen's sectional area; to have given the Total stress borne by each would only have complicated the tables without being of any real service. In the series now to be examined it was, however, better to give the total stress borne by each, so that any one can divide it by the net area, instead of the gross, should they prefer to do so.

The strength of the solid plate, or that without the holes, is taken from preceding reports, and is given in the last column to facilitate comparisons. The difference between that of the solid plate and that with the holes represents the loss due to the latter. It has already been stated in former paragraph that in forming the four holes 42·5 per cent. of the plate was removed. Now let us see the *actual* loss as ascertained by these experiments.

In the four Essen specimens with Drilled-holes, we find a mean loss of 37·2 per cent. when tested lengthway of the plate, and 38·9 per cent. when crossway; total mean being 38·05 per cent. In the nine Yorkshire under the same conditions, 43·1 and 42·8; mean 42·95 per cent; this loss agreeing very nearly with 42·50 per cent. representing the material removed. Such, however, is not the case with the Essen plates where we have a mean loss of only 38·05 instead of 42·50, difference being 4·45 per cent. This difference, however, is entirely due to the fact of the material being much softer. The ultimate stress borne by a specimen is greatly affected by the hardness or softness of the material, and by the Shape of the specimen. The softer the material the more rapidly does its sectional area become reduced by the specimen stretching, and, consequently, in the amount of Stress sustained. When the breadth of a specimen is reduced to a minimum at one point a greater resistance is offered to its stretching than

when formed parallel for some distance; and as the stretching is checked so will also the contraction of area, and with it will be an increase in the ultimate stress. In the former series of experiments, Reports A, B, C, D, the sides of the specimens being parallel they stretched more, and the Essen specimens being very considerably softer than the Yorkshire, their area became more reduced, and, accordingly, the stress borne by them was less than it would otherwise have been. In the present series the stretching of the specimens being confined to the material left between the rivet-holes across the specimens, the sectional area was not so much reduced as were the parallel specimens, and, consequently, held a proportionately higher stress, thus accounting for the loss of 38·05 per cent., being less than the 42·50 per cent. due to amount of material removed by the rivet-holes.

We will now consider the results relating to the Punched holes. The five Essen specimens tested lengthway show a mean loss of 48·5, crossway 50·0; mean 49·25 per cent. The six Yorkshire 50·0 and 52·4; mean 51·2 per cent. The mean loss in the one group being 6·75, in the other 8·70 per cent. more than that due simply to the number of holes. This loss is partly due to the injury done to the iron surrounding the holes, and partly due to the punching making the holes conical instead of parallel, thus removing more material than in those which were Drilled. The loss in the Essen specimens was somewhat less than in the others, owing to their being of softer quality.

Turning now to the Elongation of the holes that were Drilled, we have, for the Essen, 30·7 and 22·8, total mean 26·75 per cent., and Yorkshire 18·2 and 13·4, mean 15·80 per cent., difference in favour of the Essen being 10·95 per cent. To those that were Punched, for Essen 13·7 and 11·1, mean 12·4 per cent. Yorkshire, 8·3 and 7·0, mean 7·65; difference in favour of the Essen plates being 4·75 per cent.

DAVID KIRKALDY,

TESTING AND EXPERIMENTING WORKS,

99 SOUTHWARK STREET,

LONDON, S.E.

THE above Works are established for the purpose of testing and experimenting on the strength of various kinds of materials, especially IRON and STEEL, and generally Metals and their alloys, Stones, Artificial-stones, Bricks, Concrete, Cements, Wood, &c. Under a Patent obtained by me, I erected a very powerful and accurate TESTING MACHINE, which has been in constant operation for nine years, and undertake the testing of such articles as may be intrusted to me, and to report upon the results. The Apparatus is adapted for any kind of strain or stress,—Pulling, Thrusting, Bending, Twisting, Shearing, Punching, Bulging,—and to any amount, from 10 lbs. to 1,000,000 lbs. It will also test, with equal accuracy, portions of substances, as well as entire manufactured articles; ascertain, if wished, their ultimate breaking strength, or apply any amount of proof strain desired. The diversified capabilities of the Machine are fully attested by the contents of Museum.

By means of the Patent Indicator-dial, the slightest change in the form of the article under experiment, whether by extension, depression, deflection, or otherwise, is readily observed and exactly measured, and it is specially of service in testing small specimens when direct measurements cannot be taken. A vast variety of facts connected with the very important subject of the limit of elasticity, or the point at which a permanent change takes place in materials has been by its means obtained with precision, and are systematically recorded.

Arrangements have been made for applying distributed as well as central loads under Bending stress.

In addition to the above gradually-applied strains, the Machine can be adapted to test the effects of percussive, vibratory, jarring, and other impulsive strains, either independently, or in combination with a gradual strain, tensile, compressive, or otherwise.

In order that experiments may be made at an even temperature throughout the year, the Works are uniformly heated by hot-water pipes. Materials, however, may be subjected to all degrees of temperature from extreme heat to extreme cold, so as to ascertain the effects produced, both as regards the strength and the rates of expansion or contraction.

Engineers have found my Testing Machinery advantageous in determining the best proportions of various structural details, as well as the materials and variety of material specially adapted for their various requirements.

Manufacturers have also found the benefit of having their products tested, and of watching the effects produced by various modifications in the treatment.

This machine may be employed for private as well as public purposes. In many instances it will doubtless be considered essential that the results obtained shall be for the exclusive use of the individuals sending the specimens, at whose expense the trials are made. In other cases it may be considered desirable for commercial purposes to have the results of experiments known; and here, doubtless, the employment of a Testing Machine in the hands of an independent person, would be preferred to a private machine in the manufacturer's own establishment. Again, in many instances it might be quite immaterial what use was afterwards made of facts ascertained for a particular purpose. In every case, when it is desired that the result of the investigation shall be private, and instructions are sent to that effect, the strictest confidence may be relied upon. When it is intended to have the reports printed, proof sheets should always be sent for correction and revisal, for which no charge is made.

In cases of injury from boiler explosions, railway and machinery breakdowns, falling of bridges, houses, &c., it must certainly prove of consequence to have the means of ascertaining whether or not they were owing, wholly or in part, to the employment of faulty materials.

In matters of disagreement, much vexatious and costly litigation has already been saved by submitting the materials in dispute to certain tests, and abiding by the results obtained.

Every article, when received, is entered and numbered; and after being tested, stamped with the accompanying Trade Mark, as directed by Acts, Victoria 25 and 26, cap. 28; and 27 and 28, cap. 27; and thus precluded from being used for purposes of deception. Certified reports of the results are sent to those for whom the experiments are made.

The New Works having been built expressly to meet the varied requirements, and being provided with front and back entrances, large girders, beams, columns, &c., can be conveniently handled and tested, either to destruction or proved to any load required.

CONTENTS OF BUILDING.

BASEMENT.

Store-rooms, Furnace for heating, annealing, or case-hardening specimens. Furnace for melting various metals and alloys. Hot-water heating apparatus. Arrangements for preparing specimens of various cements, and water tanks for their immersion, also moulds for concrete-blocks. Smith's forge, &c.

GROUND FLOOR.—OFFICES, TESTING ROOM, TOOL ROOM.

In private office is the coloured drawing of the steam-ship "Persia," which was hung in the Royal Academy's Exhibition, 1861; being the first, and as yet the only Engineering Drawing admitted to that Institution.

The Testing Machine, and its arrangements for applying the different stresses; also the great variety of tools necessary to meet the diversified requirements. Steam Engine and boiler for working the pumps and other machinery. Three travelling cranes, for moving girders and other heavy articles. Machines and instruments for accurately weighing and measuring specimens.

FIRST FLOOR.—MACHINE ROOM.

Turning-lathes, planing, shaping, slotting, and drilling machines; tools and standard gauges, for accurately preparing such specimens as require it, previous to their being tested; also for making additional apparatus as required. Machinists' and Model Rooms. Lavatories, &c.

SECOND FLOOR.

Reserved for additional Machinery, &c.

THIRD FLOOR.—MUSEUM.

LARGE ROOM.

CASE **A.**—Containing 96 Specimens. To ascertain the Mechanical Properties of twelve Hammered Bars of various degrees of Hardness, or the behaviour of the Steel when subjected to the various Stresses which occur in Engineering Works—namely, Pulling, Thrusting, Bending, Twisting, and Shearing.

CASE **B.**—72 Specimens. Experiments on Steel Ingots cast six inches square, and to ascertain the Mechanical Effects produced by their being Hammered down to five, four, three, and two inch square Bars.

CASE **C.**—56 Specimens. To ascertain the Mechanical Effects produced on Steel Bars, by reducing to various sizes—viz., three-inch square, two-and-a-half, two, one-and-a-half, one, and half-inch square, some by Hammering, others by Rolling.

CASE **D.**—10 Specimens. To ascertain the Increments of length, with corresponding Sets, under a gradually increased Pulling Stress, Rolled Steel Plates of various Thicknesses.

CASE **E.**—10 Specimens. To ascertain the Decrements of length, with corresponding Sets, under a gradually increased Thrusting Stress, Rolled Steel Plates of various Thicknesses.

CASE **F.**—30 Specimens. To ascertain the Mechanical Effects, and the Variations caused by Difference in the Shape and Proportion of specimens, Rolled Steel Plates of various Thicknesses, tested under Pulling Stress.

CASE **G.**—20 Specimens. To ascertain the Mechanical Effects produced on Steel Plates of various Thicknesses by Holes, some Drilled, others Punched; tested under Pulling Stress.

STAND **H.**—20 Specimens. To ascertain resistance to Bulging Stress of Steel Plates of various Thicknesses. The clear tone given out, on being struck, by all the specimens, after being bulged, excepting those that buckled owing to their thinness, prove the soundness of the material, and consequently its suitability for some Engineering purposes, as well as for bells and gongs.

The above extensive series of experiments on Fagersta Steel were made for the Manufacturer, Christian Aspelin, Esq., of Westanfors and Fagersta Works, Sweden, and the results of which, with remarks thereon, are published, and copies, price ten shillings, can be obtained on the premises.

CASE **I.**—34 Specimens. Contains a portion of a broken thirteen-inch Steel Crank-shaft, made by Fried. Krupp, Esq., Essen, for the Peninsular and Oriental Company's steamship "Jeddo," which was cut up into a number of specimens and tested in order to ascertain the cause of the breakage. The specimens are placed in their relative positions, the mahogany framework representing the part cut away by the parting tool. The series comprises 16 tested under Pulling stress, 8 under Bending, 4 under Twisting, and 6 under Thrusting stress. The specimens and the results obtained conclusively proved that the subsequent fracture was caused by the treatment to which the shaft had been subjected, and was not owing to original defects in the steel or in its manufacture. These experiments further demonstrated the superiority of ascertaining *facts*, and appealing to them, instead of the costly, precarious, and with rare exceptions, unsatisfactory process of analysing and balancing conflicting *opinions* in our courts of law. In the present case witnesses prepared to depone "to the steel being as brittle as glass," were to have appeared on behalf of the Company, but after repeated delays were not forthcoming, so the manufacturer came off victorious. The appearance in Court of specimens reduced 36 per cent. in length under Thrusting stress, would have proved that the so-called "glass" was of a remarkable character.

CASE **J.**—1424 Specimens tested under Pulling stress, Wrought-iron, of British, American, Swedish, Russian, German, French and Belgium Manufacture, consisting of round, square, and flat bars; angle, tee, joist, and channel bars; plates, sheets, and hoops; large roof and bridge links; pieces cut out of railway crank-shafts, tyres, axles, rails, and fish-plates; specimens cut out of large gun which had burst; pieces out of rolled joists and riveted girders; bolts, coach-screws, and wires. The series show great variety of qualities, and also in the sizes of the pieces tested. Specimens of various forms to ascertain the effects of difference in the shape. Cast-iron, various qualities and sizes, one being twenty-five square inches area, also one sent to be proved, to show the increase of strength by using a certain "chemical mixture" in the cast-iron; the results of the testing, however, disclosed one large and six small wrought-iron bars embedded as the "chemical mixture." This specimen was only intended to be proved, not broken.

CASE **K.**—1112 Specimens tested under Pulling stress, Steel, consisting of round, square, flat and angle bars, plates, bridge-links, pieces cut out of crank-axles, railway tyres, axles, rails, steel lining of large gun which had burst; tool-steel; ingots and billet bars; wires. Specimens of various forms to ascertain the

effects of difference in the shape. Copper, brass and various alloys, cast, rolled, drawn; locomotive tubes, Lead and lead tin-lined pipes; sheet-brass, lead, zinc; copper, brass, and bronze wires.

340 Specimens tested under Thrusting stress; Steel, Wrought-iron, Cast-iron bars, pieces out of Steel and Iron rail-tops; pieces out of rolled joists and riveted girders, cast and rolled Copper and Gun-metal; extensive series of small cylindrical Copper specimens which have been subjected to various loads, from one to twenty-five thousand pounds, as standards for gunnery experiments, for the Royal Arsenal, Woolwich.

22 Specimens tested under Shearing stress; Steel, Wrought-iron, Cast-iron, and Bronze.

CASE **L**.—39 Specimens tested under Twisting stress, Steel, Wrought-iron and Cast-iron, from three inches to one inch diameter.

116 Specimens under Bending stress, Steel, Wrought-iron, and Cast-iron bars; Steel and Iron rails; Steel tyres, Steel and Iron axles, Rolled iron joists, pieces out of eight-inch Wrought-iron shaft; pieces out of Cast-iron screw propeller.

CASE **M**.—Contains a portion of a series of 203 experiments on two-inch square Bars of Crucible and Bessemer Steel of British Manufacture, some Hammered, others Rolled.

250 specimens of Leather-belting of various sizes, from twelve inches to one inch wide, both single and double, wire, thread, and lace sewn; some being tanned according to the English mode, whilst others by the Swiss, the results of the tests proving the vast superiority of the latter mode of manufacture. Tested samples of various modes of joining the pieces of belting, to ascertain their relative merits. Also Rubber-belting from six inches to one inch wide.

CASE **N**.—Contains a series of British bar-iron for chains and cables, from different districts in sets of twenty-four, from half-inch to two-and-a-half inches diameter.

TABLE—Portions of a series of seventy specimens of Indian Stones, tested under Thrusting stress, six by six, part six inches, and part twelve inches in height. Six and twelve inch cubes of various British Stones; one, two, three, four, five, and six inch Granite cubes. Doulting stone, thirty-six square inches area, and six, twelve, eighteen, twenty-four inches in height, one set being tested "on the bed," the other "against the bed;" also a similar series of eighteen Sandstones and Granites tested "on the bed." Variety of Bricks, Cement and Concrete blocks.

Various Cements, Mortars, and Bricks; cement and mortar Joints, tested under Pulling stress.

Patent Artificial-stones, Portland and Roman cements, tested under Bending stress.

A portion of an extremely interesting series of experiments to ascertain the change in the form of Tubes of various diameters, lengths, and thicknesses when subjected to Thrusting stress, and of the very marked difference in the amount of stress borne, and in the form of the curves between those tested as the tubes were drawn and those annealed.

Lead and tin-lined lead Pipes of various diameters and thicknesses, Burst by water pressure.

WALLS. Variety of steel and iron wire Ropes, from six-and-a-half to three-quarter inch circumference. Manilla, Hemp, and other ropes ranging from ten to one-inch circumference, tested under Pulling stress. Various kinds of submarine Telegraph cables, the component parts of some being tested separately. Various qualities of Canvas and Cloth also tested under Pulling stress.

FLOOR. Fractured column of brickwork, 20 inches in diameter. Fractured columns of Bath stones, 10 and 15 inches diameter, and 36 inches in height. Wrought-iron girder and granite abutment, with lead packing, which has been subjected to a Thrusting pressure of two hundred tons.

Long specimens of wrought-iron plates, angle and tee bars, prepared and tested under Pulling stress, the amount of extension in 100 inches of length being carefully ascertained at every increase of 2,000 lbs. per square inch of the specimen's sectional area, from commencement until fractured. The stress was also removed temporarily at every increase of 4,000 lbs. to ascertain when Set commenced, and its amount, or when the specimen became permanently extended. A corresponding series cut from the same plates, angle and tee bars, with the ends faced accurately in lathe, and tested under Thrusting stress; the amount of decrement or shortening in 100 inches of length being carefully noted at every increase of 2,000 lbs. per square inch of specimen's sectional area from the commencement until considerably passed the Elastic-limit of the material. The load was also removed and sets ascertained, as in preceding series. In these experiments under Thrusting stress the specimens were prevented from buckling or bending by the Trough-apparatus and its adjustments. The load on the specimen was gradually increased until the specimen suddenly stopped decreasing, showing that part of the load was taken by the trough, when of course the testing was suspended, and the specimen removed.

Variety of chains, from $2\frac{1}{2}$ inch to $\frac{1}{8}$ inch diameter; it will be observed that the good chains invariably pull out until the links close, and the chain becomes rigid before breaking, whilst others have broken with scarcely any alteration in the shape of the links. Coupling shackles and swivels; fortification ring-bolts; railway draw-hooks; screw and chain couplings.

Top of a cast-iron column, with flange for girder broken off in testing. Portion of ornamental cast-iron column, $14\frac{1}{4}$ feet long, $5\frac{1}{2}$ inches diameter, twin column $13\frac{3}{4}$ feet long, 4 inches diameter, these gave way by bending; also wrought-iron riband column 12 feet long, 7 inches diameter, which gave way by buckling; all tested under Thrusting stress.

Steel and iron railway axles and rails bent in the Testing-machine. Locomotive and carriage springs, volute, spiral and rubber buffer springs.

Large wrought-iron roof link $6'' \times 2'' \times 21$ feet, which has been pulled asunder (fracture cut off and preserved under glass), and by way of contrast, a small bolt and nut, some wires, and a specimen of Portland cement, all tested in the same machine. Portions of eighteen wrought-iron bridge links, of which ten broke in the eye or boss instead of the bar portion, proving that these links were not properly proportioned, and consequently material wasted.

Three varieties of wrought-iron bridge-strut, to ascertain the best distribution of material to resist Thrusting stress.

Fractures of riveted girder, 16 inches by 9 inches, tested under Bending stress, span 22 feet; cast-iron girder, 19 by 9 inches, span 18 feet; and four rolled joists, 10 by 5 inches, span 10 feet.

Specimens of steel and wrought-iron plates from three-quarter inch to one-eighth inch thick, tested under Bulging stress, having been flat discs, twelve inches diameter, cut out of plates, and pressed cold into their present shape in the Testing-machine. It will be observed that several have stood the test without the smallest crack, whilst others have burst when only slightly bulged.

Interesting series of experiments on Demerara Greenheart, tested under Thrusting stress, comprising twenty-two specimens turned to 2·524 inches diameter=5·00 square inches area, and of the following

lengths—2·5, 5, 10, 20, 30, 40, 50 inches; six turned to 5·644=25 square inches, 10, 50, 100 inches in length; three turned to 7·982 inches=50 square inches of area, 10, 50, 150 inches in length. These specimens being polished exhibit the peculiarities of their fracture. This series also includes square and other forms as well as circular specimens, and in addition some tested under Pulling stress and Bending stress. Turned and polished specimens of oak and fir tested under Thrusting and Pulling stresses.

Fractured portions of Dantzic, Memel, and Pitch-pine beams twelve by twelve inches, tested under Bending stress, distance between supports being twelve feet, also fractured portion of fir joists of various qualities and sizes.

Posts of English oak and Dantzic fir twelve by twelve, ten by ten, and nine by nine inches, all eight feet in length, tested under Thrusting stress; oak post twelve by twelve, with cap and base, which were tested together; also pieces cut out of fractured portions of white Riga and Dantzic fir logs, thirteen by thirteen inches, and twenty feet long. Eight turned specimens of Pitch-pine and Memel fir, 9·78 inches diameter=75·0 square inches, and 50 inches long, tested under Thrusting stress.

Models of Greenheart dock-gates tested under Bending stress, with the load distributed and the ends held by abutments.

An extensive series of iron plates, one-half and one-quarter inch thick, sixteen inches wide; others off the same plates, some having drilled holes and others punched, all fractured under Pulling stress. Attention is directed to the markings caused by the disturbance of the surface through scaling.

SMALL ROOM, NORTH.

Riveted joints, from one inch to one-quarter inch in thickness, and up to sixteen inches in width, comprising lap-joint, single and double riveted; butt-joints with single and double straps, single and double riveted. Some of the joints are machine, others hand riveted; also some have punched, whilst others have drilled holes. Also some specimens of plate joined by welding in place of riveting.

SMALL ROOM, SOUTH.

Five cases containing selected specimens from the series referred to in Kirkaldy's published "Experiments on Wrought Iron and Steel." Case 1st.—Bars, wrought iron, and steel. Case 2nd.—Plates, wrought iron, and steel. Case 3rd.—Effects of difference in the shape, effects of difference in the treatment, suddenly applied strains. Case 4th.—Screwed and chased bars, welded joints, textures developed by acid, iron "cold-rolled." Case 5th.—Specimens showing the shape, contraction of area at fracture, and extension. The prize Gold Medal of the Institution of Engineers in Scotland, for Session 1862-3, was awarded to the author.

1st January, 1875. DAVID KIRKALDY.

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REPORT F.

To ascertain the Resistance to and Effects under Bulging Stress.

The fifty-four specimens for the above tests were discs, twelve inches diameter cut out in the lathe, and pressed into an aperture ten inches diameter in my patent Testing-machine, the end of the bulger being turned to a radius of five inches. The two woodcuts which accompany the tabulated results show the form of the specimen previous to, and after the experiment. Two specimens for this test were cut out of each plate, the Maker's Brand being on one of them; one was tested as sent, unannealed, the other after being heated and annealed. The stress was gradually increased until the specimen was pushed through the aperture or until the specimen gave way either by cracking or bursting.

Sixteen out of the eighteen specimens or 88·8 per cent. cut out of the Essen plates passed through the aperture without being cracked, the other two or 11·1 per cent., burst, but not until they had very nearly passed, having been bulged, one to 3·06 inches when unannealed, the other 3·35 inches when annealed; with 3·52 inches, they would have passed through. Twelve out of the thirty-six Yorkshire plates, or 33·3 per cent., passed through uncracked, four or 11·1 per cent. cracked when bulged to a mean of 3·23 inches, the remaining twenty or 55·5 per cent. burst—the lowest when only bulged 1·40 inches, the highest, 3·30 inches; the mean being of 2·43 inches. Of those that passed through the aperture uncracked, we have 88·8 per cent. Essen, against 33·3 per cent. Yorkshire; and of these cracked or burst, 11·1 per cent. of Essen, against 66·6 per cent. of Yorkshire.

The mean thicknesses of the Essen specimens were ·440, ·533, ·653, mean of the whole ·542 inch; that of the Yorkshire ·390, ·510, ·625, total mean ·508 inch. The mean Ultimate stress reached being for Essen 139,093, 163,963, 217,406, mean 173,487 lbs. when tested unannealed, and 124,090, 159,683, 198,926, mean 160,900 lbs. when annealed, total mean being 167,194 lbs. For the Yorkshire, under the same circumstances, 91,805, 136,711, 165,375, mean 131,297 lbs. unannealed, and 106,081, 125,096, 173,128, mean 134,768 lbs. annealed, total mean 133,033 lbs. We have thus, with a mean thickness of ·542 inch in the Essen plates, a mean Ultimate stress of 167,194, against 133,033 lbs., with ·508 inch mean thickness in the Yorkshire plates. Dividing the stress by the thickness we have 308,476 against 261,876, showing a difference in favour of Essen of 17·8 per cent.

REPORT G.

To ascertain the Resistance to and Effects under Bending Stress.

These one-hundred-and-eight experiments were made in order to meet the Admiralty requirements regarding Cold and Hot Bending tests. They were not, however, bent by the blows of a hammer, which I have always considered objectionable, as so very much depends upon the skill of the workman, the force, the number and position of the blows, whether a specimen stands or does not stand being bent to the required angle. Two strips were cut out lengthway of each plate, and two crossway, and the edges planed parallel, and all exactly two-and-a-half inches wide. The specimens were placed against supports ten inches apart, in my Testing-machine, and loaded in the centre, as represented in the woodcuts, until the specimen dropped through between supports, having been bent, as shewn by the dotted lines. They were then replaced in the testing-machine, and the ends of those specimens tested *cold* were pressed, as in woodcut, until the distance apart was four times the nominal thickness of the plate, provided the specimen remained uncracked; those tested *hot* were doubled up and pressed together, as shown by the other woodcut. The specimens bent hot were all heated to as nearly the same colour, "cherry-red," as was practicable.

Referring to specimens tested Cold, thirteen out of the eighteen, or 72·2 per cent. of the Essen strips were bent as stated, without the slightest crack; three, or 16·6 per cent., were very slightly cracked, and two, or 11·1 per cent., were cracked; all being bent to 180 degrees. Five out of the thirty-six, or 13·8 per cent., of the Yorkshire were uncracked; six, or 16·6 per cent., were cracked slightly, these eleven stood bending to 180 degrees; twenty-five, or 69·4 per cent., were cracked, the lowest on reaching an angle of 50 degrees, the highest 180 degrees, mean of the twenty-five being 141 degrees. Of those uncracked, we have 72·2 of the Essen against 13·8, the difference in favour of Essen thus being 58·4 per cent.

Of those tested Hot, being doubled up and pressed together, seventeen, or 94·4 per cent., of the Essen strips were uncracked, and one, or 5·5 per cent., cracked slightly. Twenty, or 55·5 per cent. of the Yorkshire were uncracked, six, or 16·6 per cent., cracked slightly; five, or 13·8 per cent. cracked; three, or 8·3 per cent. were cracked badly; and two, or 5·5 per cent. were nearly separated. Of those uncracked, we have 94·4 of the Essen against 55·5 of the Yorkshire, difference in favour of Essen 38·9 per cent.

On comparing the amount of Stress, we have for those tested Cold, lengthway and crossway of plate, for Essen 2553. 2445, 3211, 3061, 4718, 4735, total mean 3454 lbs., with a total mean thickness of plate ·548 inch. Yorkshire strips 1552, 1645, 2203, 2360, 4415, 4281, total mean 2743 lbs. with ·507 mean thickness. Dividing the stress by the thickness we obtain 6303 for the first, and 5410 for the second; difference in favour of Essen being 16·5 per cent. Similarly comparing those tested Hot, we have 532, 605, 742, 672, 1049, 1020, total mean 770 lbs. for Essen, and 460, 528, 654, 622, 746, 828, total mean 640 lbs. for Yorkshire. Dividing the stress by the thickness we have 1405 against 1262; difference in favour of Essen 11·3 per cent.

CONCLUDING REMARKS.

Summing up the various facts obtained during this inquiry, stated in the tabulated reports and in the remarks thereupon, we have the following total mean results :—

			Essex.	Yorkshire.
Pulling Stress	Reports A, B, C, D	Elastic Stress	25,144 lbs.	27,477 lbs.
		Ultimate Stress	48,028 do.	45,515 do.
		Stress per Fractured Area	74,542 do.	56,875 do.
		Contraction of Area	33·8 per cent.	18·6 per cent.
		Extension at 30,000 lbs.	1·94 do.	0·85 do.
		Extension at 40,000 lbs.	7·76 do.	6·41 do.
		Extension Ultimate	22·70 do.	14·80 do.
Pulling Stress	Report E	Loss due to Holes, Drilled	38·05 do.	42·93 do.
		do. do. Punched	49·25 do.	51·20 do.
		Elongation of Holes, Drilled	26·75 do.	15·80 do.
		do. do. Punched	12·40 do.	7·65 do.
Bulging Stress	Report F	Uncracked	88·8 do.	33·3 do.
		Cracked or Burst	11·1 do.	66·6 do.
		Bulged	3·36 inches	2·80 inches
		Thickness	·542 inch	·508 inch
		Ultimate Stress	167,194 lbs.	133,033 lbs.
Bending Stress	Report G	Tested Cold, Uncracked	72·2 per cent.	13·8 per cent.
		do. do. Cracked	27·7 per cent.	86·1 per cent.
		do. do. Angle	180 degrees	152 degrees
		do. do. Thickness	·548 inch	·507 inch
		do. do. Ultimate Stress	3454 lbs.	2743 lbs.
		Tested Hot, Uncracked	94·4 per cent.	55·5 per cent.
		do. do. Cracked	5·5 per cent.	44·2 per cent.
		do. do. Angle	180 degrees	180 degrees
		do. do. Thickness	·548 inch	·507 inch
		do. do. Ultimate Stress	770 lbs.	640 lbs.

These varied differences between the Essen and the Yorkshire plates are fully attested by the appearance presented by their respective fractures. The Essen plates exhibiting generally a lighter shade than the others, and much more uniform. The Yorkshire plates presenting layers of several shades, some being considerably darker than the others, whilst many of the specimens are chiefly composed of dark layers. In the tabulated reports, the different Yorkshire Firms are placed in their respective order of merit, as nearly as practicable, from the results of their individual specimens.

Finally, I beg to state that none of the facts ascertained throughout this inquiry have been concealed, but that I have presented the whole in the most suitable form for comparison, and in order that all may have the opportunity of judging for themselves and of drawing their own conclusions.

Testing and Experimenting Works,
99 Southwark Street, London, S.E.,
31st December, 1875.

DAVID KIRKALDY.

TABULATED REPORTS.

REPORT A.

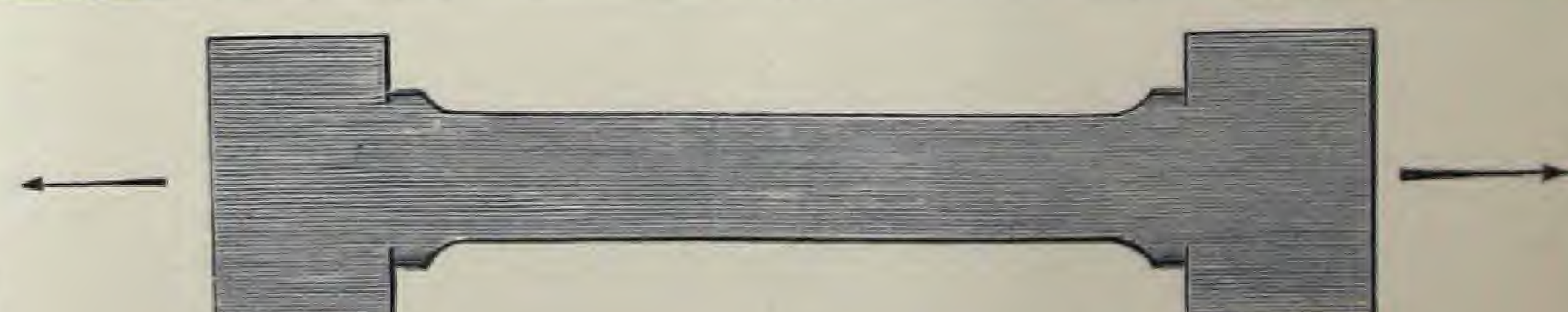
SUMMARY OF THE RESULTS OF EXPERIMENTS TO ASCERTAIN THE ELASTIC

NOMINAL THICKNESS—

Description.	LENGTHWAY.													
	Brand.	Test No.	Thickness.	STRESS. Elastic, per square inch.		STRESS. Ultimate, per square inch.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	EXTENSION, SET At 30,000 lbs. per square inch.	EXTENSION, SET At 40,000 lbs. per square inch.	EXTENSION, SET Ultimate.	Appearance of Fracture.
		J	inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent	lbs.	per cent.	per cent.	per cent.	
UNANNEALED	Krupp	1559	·44	29,500	13·1	54,540	24·3	54·0	39·3	89,878	0·40	3·77	26·1	Fibrous.
	do.	1549	·44	28,300	12·6	52,595	23·5	53·8	44·3	94,455	0·62	4·80	29·8	do.
	do.	1539	·44	27,500	12·2	50,215	22·4	54·7	43·4	88,733	0·79	6·08	27·7	do.
		Mean	**·440**	**28,433**	**12·7**	**52,450**	**23·4**	**54·2**	**42·3**	**91,022**	**0·60**	**4·88**	**27·8**	
	Bowling	1878	·40	32,900	14·7	57,415	25·6	57·3	29·5	81,439	0·10	2·82	22·6	Fibrous.
	Taylor's	1938	·39	29,500	13·2	50,865	22·7	57·9	19·7	63,378	0·19	4·71	19·5	do.
	Lowmoor	1848	·38	25,800	11·5	47,050	21·0	54·8	30·5	67,723	2·30	8·30	24·4	do.
	Monkbridge	1998	·37	28,300	12·6	47,845	21·3	59·1	19·4	59,205	0·37	5·00	14·3	do.
	Farnley	1908	·42	27,500	12·2	45,160	20·1	60·8	14·0	52,540	0·89	5·87	11·8	part do. flaw.
	Cooper & Co.	1968	·38	27,500	12·2	45,080	20·1	61·0	18·4	55,259	0·72	5·29	12·2	dark do. layers.
		Mean	**·390**	**28,583**	**12·7**	**48,902**	**21·8**	**58·5**	**21·9**	**63,257**	**0·76**	**5·33**	**17·5**	
ANNEALED.	Krupp	1550	·44	25,900	11·9	46,435	20·7	55·7	50·5	93,937	2·75	8·61	31·0	Fibrous.
	do	1560	·44	25,700	11·5	46,290	20·6	55·5	45·7	85,398	2·80	8·70	29·3	do.
	do.	1540	·44	24,500	11·0	45,070	20·1	54·3	42·2	78,074	3·23	9·98	27·3	do.
		Mean	**·440**	**25,366**	**11·3**	**45,932**	**20·9**	**55·2**	**46·1**	**85,803**	**2·93**	**9·09**	**29·2**	
	Bowling	1879	·39	29,300	13·1	50,260	22·4	58·2	26·0	67,942	0·21	5·40	20·6	Fibrous.
	Taylor's	1939	·39	28,700	12·7	49,140	21·9	58·4	36·1	76,966	0·25	6·65	26·3	do.
	Lowmoor	1849	·38	23,200	10·4	43,580	19·4	53·2	30·1	62,374	3·50	12·20	25·4	do.
	Monkbridge	1999	·37	24,900	11·1	44,020	19·6	56·5	23·7	57,756	1·37	7·65	20·1	do.
	Cooper & Co.	1969	·38	26,300	11·7	41,905	18·7	62·7	13·7	48,548	2·11	9·18	12·5	dark do. layers.
	Farnley	1909	·41	24,600	11·0	40,105	17·9	61·3	12·5	45,866	2.60	10·10	11·0	dark do. layers.
		Mean	**·386**	**26,166**	**11·6**	**44,835**	**20·0**	**58·4**	**23·7**	**59,908**	**1·67**	**8·53**	**19·3**	

FRIED. KRUPP, Esq.,

ESSEN WORKS, RHENISH PRUSSIA ;



2 CROWN BUILDINGS, QUEEN VICTORIA STREET, LONDON, E.C.

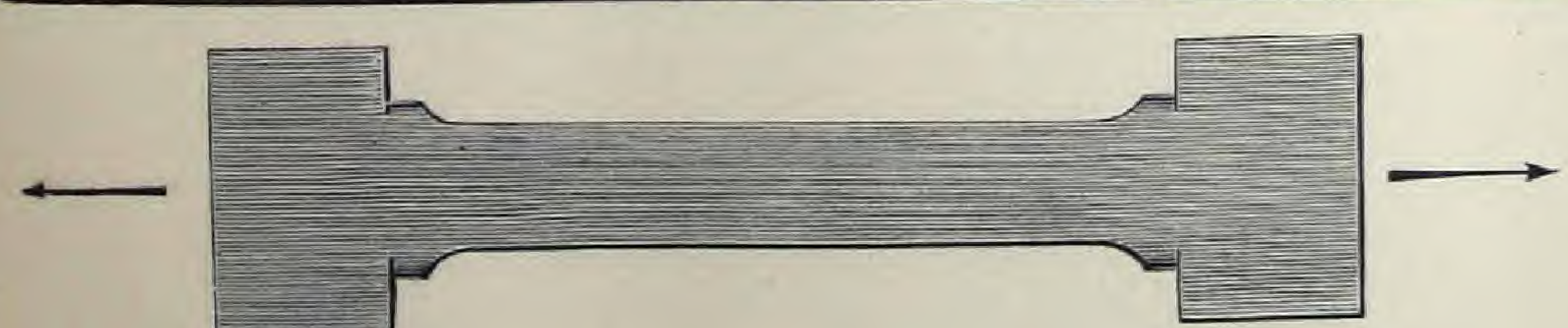
REPORT A.

AND ULTIMATE TENSILE STRENGTH OF NINE WROUGHT-IRON PLATES.

THREE-EIGHT INCH.

CROSSWAY.

Description.	Brand.	Test No.	Thickness.	Stress. Elastic, per square inch. lbs.	Stress. Elastic, per square inch. tons.	Stress. Ultimate, per square inch. lbs.	Stress. Ultimate, per square inch. tons.	Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	Extension, set. At 30,000 lbs. per square inch.	Extension, set. At 40,000 lbs per square inch.	Extension, set. Ultimate.	Appearance of Fracture.
		J	inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent.	lbs.	per cent.	per cent.	per cent.	
UNANNEALED.	Krupp	1551	·44	28,800	12·8	50,195	22·4	57·3	27·2	69,018	0·22	4·98	16·6	Fibrous.
	do.	1561	·44	27,700	12·4	50,430	22 5	54·9	23·1	65,648	0·40	4·72	15·8	do.
	do.	1541	·44	26,400	11·8	47,240	21·1	55·8	16·8	56,791	0·60	5·90	14·8	slight do. flaw.
		Mean	**·440**	**27,633**	**12·3**	**49,288**	**22·0**	**56·0**	**22·3**	**63,891**	**0·41**	**5·20**	**15·7**	
	Bowling	1880	·41	29,800	13·3	51,610	23·0	57·7	30·3	74,115	0·13	4·30	19·3	Fibrous.
	Farnley	1910	·40	29,100	13·0	50,840	22·7	57·2	23·1	66,133	0·21	4·32	16·4	do.
	Lowmoor	1850	·38	27,300	12·2	48,460	21·6	56·3	15·9	57,636	0·57	5·60	14·7	do.
	Taylor's	1940	·39	28,500	12·7	41,095	18·4	69·3	7·9	44,643	0·29	4·30	5·3	do.
	Monkbridge	2000	·37	27,200	12·2	40,140	17·9	67·7	7·8	43,555	0·59	4·75	5·2	dark do. layers.
	Cooper & Co.	1970	·38	26,600	11·9	40,070	18·4	66·3	8·1	43,629	1·00	5·66	6·1	dark do. layers.
		Mean	**·388**	**28,083**	**12·5**	**45,369**	**20·2**	**62·4**	**15·5**	**54,952**	**0·46**	**4·82**	**11·1**	
ANNEALED.	Krupp	1552	·44	24,800	11·1	47,905	21·4	51·7	29·3	67,775	1·70	6·68	19·6	Fibrous.
	do.	1542	·44	24,600	11.0	44,945	20·1	54·7	20·7	56,022	1·91	7·74	16·0	do.
	do.	1562	·44	23,500	10·5	44,860	20·0	52·3	16·3	53,636	2·48	7·29	13·9	slight do. flaw.
		Mean	**·440**	**24,300**	**10·9**	**45,903**	**20·5**	**52·9**	**22·1**	**59,144**	**2·03**	**7·24**	**16·5**	
	Farnley	1911	·40	29,300	13·1	46,890	20·9	62·4	26·6	63,704	0·18	6·10	18·2	Fibrous.
	Bowling	1881	·41	29,500	13·2	46,915	20·9	62·8	22·4	60,358	0·11	6·29	15·3	do.
	Lowmoor	1851	·38	26,200	11·7	44,840	20·0	58·4	14·8	52,671	2·17	7·64	13·9	do.
	Monkbridge	2001	·37	27,000	12·1	40,970	18·2	65·9	11·3	46,216	0·76	6·00	7·7	dark do. layers.
	Cooper & Co.	1971	·38	25,800	11·5	35,980	16·1	71·7	7·6	38,952	1·29	....	6·2	dark do. layers.
	Taylor's	1941	·39	25,600	11·4	35,060	15·6	73·0	8·9	38,516	1·28	....	5·8	bad do. welds.
		Mean	**·388**	**27,233**	**12·2**	**41,776**	**18·6**	**65·7**	**15·2**	**50,069**	**0·96**	**6·50**	**11·2**	



Length for Extension, 10 inches. Breadth, 2·00 inches.

99 SOUTHWARK STREET, LONDON, S.E., 17th September, 1875.

DAVID KIRKALDY.

REPORT B.

SUMMARY OF THE RESULTS OF EXPERIMENTS TO ASCERTAIN THE ELASTIC

NOMINAL THICKNESS,

LENGTHWAY.

Description.	Brand.	Test No.	Thickness.	Stress. Elastic, per square inch.		Stress. Ultimate, per square inch.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	Extension, set. At 30,000 lbs. per square inch.	Extension, set. At 40,000 lbs. per square inch.	Extension, set. Ultimate.	Appearance of Fracture.
		J	inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent.	lbs.	per cent.	per cent.	per cent.	
UNANNEALED.	Krupp	1579	·54	25,900	11·6	52,275	23·3	49·5	32·3	77,232	1·19	4·24	24·1	Fibrous.
	do.	1589	·53	25,600	11·5	52,445	23·4	48·8	37·3	83,722	1·38	4·33	26·2	do.
	do.	1569	·53	25,200	11·2	51,780	23·1	48·6	44·4	93,186	1·50	4·80	27·6	do.
		Mean	**·533**	**25,566**	**11·3**	**52,167**	**23·2**	**48·9**	**38·0**	**84,713**	**1·36**	**4·46**	**25·9**	
	Lowmoor	1858	·50	26,800	12·0	51,740	23·1	51·7	27·9	71,761	0·79	4·00	19·5	Fibrous.
	Taylor's	1948	·51	28,200	12·6	47,770	21·2	59·0	34·9	73,380	0·32	6·80	21·9	do.
	Farnley	1918	·52	28,700	12·8	50,785	22·6	56·5	19·5	63,102	0·21	4·12	17·8	do.
	Cooper & Co.	1978	·53	28,600	12·7	45,580	20·3	62·7	18·0	55,598	0·21	6·82	14·9	def. do. welds.
	Bowling	1888	·49	26,500	11·8	44,310	19·8	59·8	17·7	53,875	1·48	7·10	14·2	dark do. layers.
	Monkbridge	2008	·51	27,900	12·5	44,215	19·7	63·1	11·5	50,000	0·40	5·92	10·7	dark do. layers.
		Mean	**·510**	**27,783**	**12·4**	**47,400**	**21·1**	**58·8**	**21·6**	**61,286**	**0·57**	**5·79**	**16·5**	
ANNEALED.	Krupp	1570	·53	24,300	10·9	46,605	20·8	51·0	49·7	94,674	2·60	7·55	29·2	Fibrous.
	do.	1590	·53	24,600	11·0	47,430	21·1	51·8	47·6	90,586	2·52	7·50	26·2	do.
	do.	1580	·54	24,900	11·1	46,635	20·8	53·3	38·1	75,377	2·50	7·92	23·8	do.
		Mean	**·533**	**24,600**	**11·0**	**47,223**	**21·1**	**52·0**	**45·1**	**86,879**	**2·54**	**7·66**	**26·4**	
	Lowmoor	1859	·49	26,400	11·7	46,355	20·7	56·0	33·2	69,461	1·70	8·22	23·1	Fibrous
	Farnley	1919	·52	28,100	12·5	47,285	21·1	59·3	28·0	65,882	0·80	7·37	22·6	do.
	Cooper & Co.	1979	·53	28,500	12·7	45,870	20·5	62·1	21·0	58,091	0·41	7·60	18·6	do.
	Taylor's	1949	·51	26,800	12·0	43,405	19·4	61·7	26·2	58,873	2·28	12·00	21·5	dark do. layers.
	Monkbridge	2009	·50	27,600	12·3	44,485	19·8	62·0	17·3	53,790	0·70	7·43	13·1	dark do. layers
	Bowling	1889	·48	23,800	10·6	41,980	18·7	56·6	7·2	51,013	3·20	13·00	18·1	dark do. layers.
		Mean	**505**	**26,866**	**12·0**	**44,913**	**20·1**	**59·6**	**22·1**	**59,518**	**1·51**	**9·27**	**19·5**	

FRIED. KRUPP, Esq.,

ESSEN WORKS, RHENISH PRUSSIA;

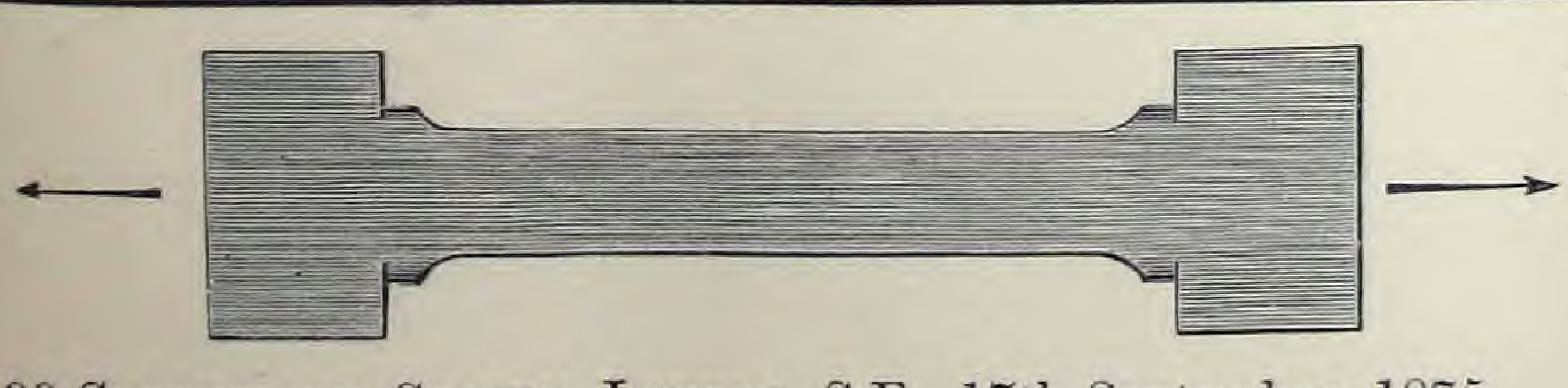
2 CROWN BUILDINGS, QUEEN VICTORIA STREET, LONDON, E.C.

REPORT B.

AND ULTIMATE TENSILE STRENGTH OF NINE WROUGHT-IRON PLATES.

HALF-INCH.

Description.	CROSSWAY.													
	Brand.	Test No.	Thickness.	STRESS. Elastic, per square inch.		STRESS. Ultimate, per square inch.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	EXTENSION, SET At 30,000 lbs. per square inch.	EXTENSION, SET At 40,000 lbs. per square inch.	EXTENSION, SET Ultimate.	Appearance of Fracture.
		J	inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent.	lbs.	per cent.	per cent.	per cent.	
UNANNEALED.	Krupp	1571	·52	25,400	11·4	52,135	23·3	48·7	28·0	72,487	1·02	3·70	17·4	Fibrous.
	do.	1591	·53	25,300	11·3	51,445	22·9	49·1	25·7	69,290	1·20	4·02	19·3	do.
	do.	1581	·54	25,100	11·1	47,340	21·1	53·0	21·2	60,078	1.81	6·13	15·8	do.
		Mean	**·530**	**25,266**	**11·2**	**50,307**	**22·4**	**50·2**	**24·9**	**67,285**	**1·34**	**4·62**	**17·7**	
	Farnley	1920	·49	29,800	13·4	56,470	25·2	52·7	15·1	66,514	0·17	2·54	18·3	Fibrous.
	Monkbridge	2010	·51	29,100	13·0	45,590	20·3	63·8	16·1	52,542	0·19	4·90	10·3	do.
	Taylor's	1950	·51	28,700	12·8	45,965	20·5	62·4	8·2	50,090	0·22	3·40	8·0	do.
	Cooper & Co.	1980	·52	28,200	12·6	42,810	19·8	65·8	14·6	50,137	0·60	6·55	9·1	dark do. layers.
	Bowling	1890	·50	26,300	11·7	40,920	18·2	64·2	8·8	44,868	0·60	4·77	6·2	dark do. layers.
	Lowmoor	1860	·50	29,100	13·0	40,145	17·9	65·0	14·9	47,173	0·88	7·72	9·4	bad do. welds.
		Mean	**·505**	**28,033**	**12·5**	**45,316**	**20·2**	**62·3**	**12·9**	**51,887**	**0·44**	**4·98**	**10·2**	
ANNEALED.	Krupp	1592	·53	24,500	11·0	46,745	20·8	52·4	35·3	72,335	2·41	7·14	22·4	Fibrous.
	do.	1582	·53	24,700	11·1	46,985	20·9	52·5	20·3	60,911	2·30	7·40	20·2	do.
	do.	1572	·52	24,400	10·9	44,940	20·1	54·2	27·2	61,740	2·40	7·94	16·8	do.
		Mean	**·526**	**24,533**	**11·0**	**46,223**	**20·6**	**53·0**	**27·6**	**64,995**	**2·37**	**7·49**	**19·8**	
	Farnley	1921	·49	29,600	13·2	49,870	22·2	59·3	25·5	68,291	0·20	4·97	19·5	Fibrous.
	Lowmoor	1861	·50	26,200	11·6	44,660	19·9	58·6	32·8	64,970	1·40	9·99	22·2	do.
	Taylor's	1951	·51	27,100	12·1	44,605	19·9	60·7	20·5	56,181	1·20	8·89	17·6	do.
	Monkbridge	2011	·50	28,500	12·7	46,590	20·7	61·1	14·1	54,237	0·48	5·40	12·0	dark do. layers.
	Cooper & Co.	1981	·51	27,800	12·4	40,825	18·2	67·9	12·4	46,699	0·89	8·40	10·2	dark do. layers.
	Bowling	1891	·50	24,300	10·9	38,365	17·1	63·3	9·8	42,533	1·91	....	7·3	dark do. layers.
		Mean	**·501**	**27,250**	**12·1**	**44,164**	**19·6**	**61·8**	**19·2**	**55,485**	**1·01**	**7·53**	**14·8**	



Length for Extensions, 10 inches, Breadth, 2·00 inches.

99 SOUTHWARK STREET, LONDON, S.E., 17th September, 1875. DAVID KIRKALDY.

TESTING & EXPERIMENTING WORKS DAVID KIRKALDY TEST MARK LONDON.

REPORT C.

SUMMARY OF THE RESULTS OF EXPERIMENTS TO ASCERTAIN THE ELASTIC

NOMINAL THICKNESS—

LENGTHWAY.

DESCRIPTION.	Brand.	Test No.	Thickness.	STRESS. Elastic, per square inch		Ultimate, per square inch		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	EXTENSION, SET At 30,000 lbs. per square inch.	At 40,000 lbs. per square inch.	Ultimate.	APPEARANCE OF FRACTURE.
		J	inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent.	lbs.	per cent.	per cent.	per cent.	
UNANNEALED.	Krupp	1619	·65	24,200	10·8	47,460	21·1	50·9	47·6	90,599	2·48	7·97	29·8	Fibrous.
	do.	1609	·66	25,400	11·4	49,935	22·2	50·8	39·7	82,911	1·40	4·82	22·1	do.
	do.	1599	·65	24,200	10·8	47,070	21·0	51·4	28·2	65,585	1·97	6·43	16·4	def. do. weld.
		Mean	**·653**	**24,600**	**11·0**	**48,155**	**21·5**	**51·0**	**38·5**	**79,698**	**1·95**	**6·41**	**22·7**	
	Lowmoor	1868	·63	28,600	12·7	50,405	22·5	56·7	20·9	66,433	0·40	5·10	21·6	Fibrous.
	Bowling	1898	·62	26,800	12·0	50,030	22·4	53·5	21·2	63,497	0·60	5·32	20·4	do.
	Taylor's	1958	·63	26,500	11·9	49,465	22·1	53·5	24·7	63,491	0·64	5·76	23·0	do.
	Cooper & Co.	1988	·63	25,300	11·3	47,770	21·2	52·9	21·0	60,492	0·98	5·83	15·6	dark do. layers.
	Farnley	1928	·64	29,200	13·0	47,760	21·2	61·1	14·8	56,085	0·21	3·88	10·2	dark do. layers.
	Monkbridge	2018	·61	27,800	12·4	39,233	17·6	70·8	8·7	43,263	1·02	....	6·5	dark do. layers.
		Mean	**·627**	**27,366**	**12·2**	**47,444**	**21·2**	**58·1**	**18·5**	**58,877**	**0·64**	**5·18**	**16·2**	
ANNEALED.	Krupp	1620	·65	23,200	10·4	46,215	20·6	50·2	43·1	81,298	3·04	9·90	32·1	Fibrous.
	do.	1600	·63	23,500	10·5	46,890	20·9	50·1	40·1	78,357	2·81	8·20	29·7	do.
	do.	1610	·66	24,600	11·0	48,275	21·6	50·9	36·5	76,132	2·22	7·28	25·9	do.
		Mean	**·646**	**23,766**	**10·7**	**47,126**	**21·0**	**50·4**	**39·9**	**78,596**	**2·69**	**8·46**	**29·2**	
	Lowmoor	1869	·63	29,200	13·0	52,060	23·2	56·0	29·6	73,952	0·33	5·30	23·4	Fibrous.
	Bowling	1899	·62	26,100	11·6	47,860	21·3	54·5	28·7	65,906	2·20	7·11	22·7	do.
	Taylor's	1959	·63	27,500	12·2	47,405	21·1	58·0	21·9	60,763	1·55	6·94	23·5	do.
	Cooper & Co.	1989	·63	29,400	13·1	46,240	20·6	60·3	16·9	55,647	0·12	5·05	12·0	dark do. layers.
	Farnley	1929	·64	28,500	12·7	44,920	20·1	63·4	15·7	53,287	0·28	7·28	13·2	dark do. layers.
	Monkbridge	2019	·60	27,200	12·1	36,700	16·4	74·0	13·8	42,593	1·99	....	5·1	dark, do. flaw.
		Mean	**·625**	**27,983**	**12·5**	**45,866**	**20·2**	**61·0**	**21·0**	**58,858**	**1·08**	**6·33**	**16·6**	

FRIED. KRUPP, Esq.,

ESSEN WORKS, RHENISH PRUSSIA ;

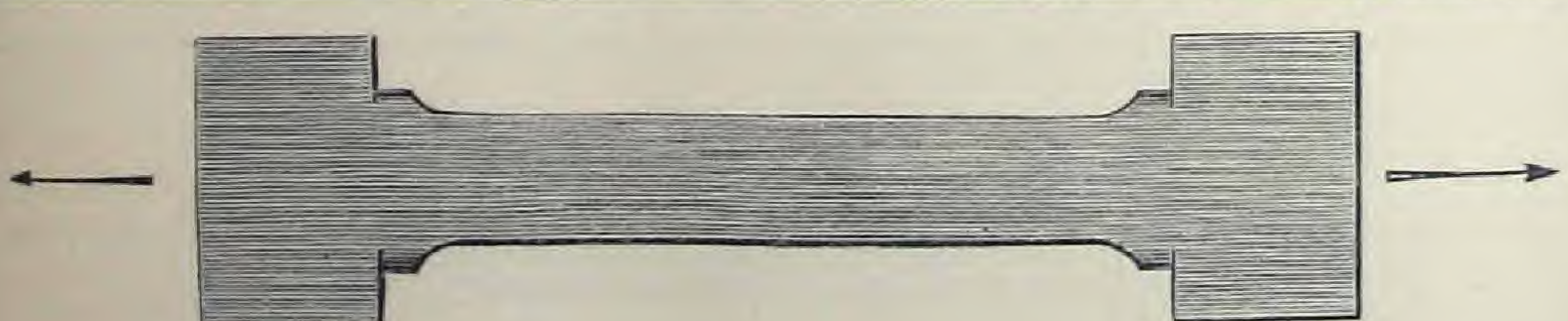
2 CROWN BUILDINGS, QUEEN VICTORIA STREET, LONDON, E.C.

REPORT C.

AND ULTIMATE TENSILE STRENGTH OF NINE WROUGHT-IRON PLATES.

FIVE-EIGHT INCH.

Description.	CROSSWAY.													
	Brand.	Test No.	Thickness.	STRESS. Elastic, per square inch.		STRESS. Ultimate, per square inch.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	EXTENSION, SET At 30,000 lbs. per square inch.	EXTENSION, SET At 40,000 lbs. per square inch.	EXTENSION, SET Ultimate.	Appearance of Fracture.
		J	inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent.	lbs.	per cent.	per cent.	per cent.	
UNANNEALED.	Krupp	1621	·65	24,200	10·8	46,635	20·8	51·8	37·2	74,295	2·60	8·07	24 4	Fibrous.
	do.	1611	·66	24,600	11·0	47,860	21·3	51·3	27·5	66,013	2·11	6·40	18·8	do.
	do.	1601	·65	23,400	10·4	45,190	20·1	51·7	16·9	54,395	2·20	6·82	13·2	def. do. weld.
		Mean	**·653**	**24,066**	**10·7**	**46,561**	**20·8**	**51·6**	**27·2**	**64,901**	**2·30**	**7·10**	**18·8**	
	Lowmoor	1870	·63	29,500	13·2	51,390	22 9	57·4	23·2	66,961	0·11	4·10	16·4	Fibrous.
	Bowling	1900	·61	24,800	11·1	46,780	20·9	53·0	21·9	59,948	1·70	6·22	19·0	do.
	Cooper & Co.	1990	·63	28,600	12·7	47,020	21·0	60·8	17·9	57,296	0·30	5·00	12·5	do.
	Farnley	1930	·63	27,500	12·3	47,345	21·1	58·0	11·9	53,791	0 60	4·50	10·1	dark do. layers.
	Monkbridge	2020	·61	28,200	12·6	43,635	19·0	64·6	13·0	50,174	0·40	5·70	9·4	dark do. layers.
	Taylor's	1960	·63	26,600	11·9	41,590	18·5	63·9	7·1	44,788	0·68	5·78	6·8	dark do. layers.
		Mean	**·623**	**27,533**	**12 2**	**46,293**	**20·6**	**59·6**	**15 8**	**55,493**	**0·63**	**5·21**	**12·3**	
ANNEALED.	Krupp	1622	·65	24,500	11·0	45,110	20·1	54·3	44·6	81,448	2·98	9·90	29·2	Fibrous.
	do.	1612	·65	23,600	10·5	45,690	20·3	51·6	32 7	67,958	2·64	8·05	23·5	do.
	do.	1602	·64	22,700	10·1	44,220	19·7	51·3	17·1	53,347	2·50	7·86	15.0	def. do. weld.
		Mean	**·646**	**23,600**	**10 5**	**45,007**	**20·1**	**52 4**	**31·5**	**67,584**	**2·71**	**8·60**	**22·8**	
	Lowmoor	1871	·63	29,200	13 0	48,020	21·5	60 8	26·8	65,623	0·16	5·38	16·3	Fibrous.
	Bowling	1901	·60	24,180	10·7	41,335	18·5	58·3	20·6	52,102	3·91	14·20	19·1	do.
	Cooper & Co.	1991	·62	27,800	12·4	44,860	20·0	61·9	14·6	52,576	0·60	5·88	11·1	do.
	Farnley	1931	·63	27,100	12·1	43,940	19·6	61·6	11·1	49,476	1·03	5·96	9·6	dark do. layers.
	Monkbridge	2021	·61	27,400	12·2	42,735	19·1	64·1	15·9	50,815	0·82	6 78	9·3	dark do. layers.
	Taylor's	1961	·62	25,500	11 4	42,555	19·0	59·9	9·2	46,904	1·67	6·60	9·2	dark do. layers.
		Mean	**·618**	**26,850**	**12·0**	**43,907**	**19 6**	**61·1**	**16·3**	**52,916**	**1 36**	**7·46**	**12·4**	



Length for Extensions, 10 inches. Breadth, 2 00 inches.

99 SOUTHWARK STREET, LONDON, S.E., 17th September, 1875.

DAVID KIRKALDY.

REPORT D.

GENERAL SUMMARY OF THE RESULTS OF EXPERIMENTS TO ASCERTAIN THE

NOMINAL THICKNESS—THREE-EIGHT,

LENGTHWAY.

Description.	Brand.	Number of Tests.	Thickness.	Stress. Elastic. per square inch. lbs.	Stress. Elastic. per square inch. tons.	Stress. Ultimate. per square inch. lbs.	Stress. Ultimate. per square inch. tons.	Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	Extension, set. At 30,000 lbs. per square inch.	Extension, set. At 40,000 lbs. per square inch.	Extension, set. Ultimate.	Appearance of Fracture.
			inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent.	lbs.	per cent.	per cent.	per cent.	
UNANNEALED.	Krupp	Mean of 3	·440	28,433	12·7	52,450	23·4	54·2	42·3	91,022	0·60	4·88	27·8	Fibrous.
	do.	Mean of 3	·533	25,566	11·3	52,167	23·2	48·9	38·0	84,713	1·36	4·46	25·9	do.
	do.	Mean of 3	·653	24,600	11·0	48,155	21·5	51·0	38·5	79,698	1·95	6·41	22·7	do.
		Mean of 9	·542	26,199	11·6	50,924	22·7	51·3	39·6	85,144	1·30	5·25	25·4	do.
	Yorkshire	Mean of 6	·390	28,583	12·7	48,902	21·8	58·5	21·9	63,257	0·76	5·33	17·5	Fibrous.
	do.	Mean of 6	·510	27,783	12·4	47,400	21·1	58·8	21·6	61,286	0·57	5·79	16·5	do.
	do.	Mean of 6	·627	27,366	12·2	47,444	21·2	58·1	18·5	58,877	0·64	5·18	16·2	do.
		Mean of 18	·509	27,910	12·4	47,915	21·3	58·4	20·6	61,140	0·65	5·43	16·7	do.
ANNEALED.	Krupp	Mean of 3	·440	25,366	11·3	45,932	20·9	55·2	46·1	85,803	2·93	9·09	29·2	Fibrous.
	do.	Mean of 3	·533	24,600	11·0	47,223	21·1	52·0	45·1	86,879	2·54	7·66	26·4	do.
	do.	Mean of 3	·646	23,766	10·7	47,126	21·0	50·4	39·9	78,596	2·69	8·46	29·2	do.
		Mean of 9	·539	24,577	11·0	46,760	21·0	52·5	43·7	83,759	2·72	8·40	28·2	do.
	Yorkshire	Mean of 6	·386	26,166	11·6	44,835	20·0	58·4	23·7	59,908	1·67	8·53	19·3	Fibrous.
	do.	Mean of 6	·505	26,866	12·0	44,913	20·1	59·6	22·1	59,518	1.51	9·27	19·5	do.
	do.	Mean of 6	·623	27,983	12·5	45,866	20·2	61·0	21·0	58,858	1·08	6·33	16·6	do.
		Mean of 18	·504	27,005	12·0	45,204	20·1	59·6	22·2	59,428	1·42	8·04	18·4	do.

FRIED. KRUPP, Esq.,

ESSEN WORKS, RHENISH PRUSSIA;

2 CROWN BUILDINGS, QUEEN VICTORIA STREET, LONDON, E.C.

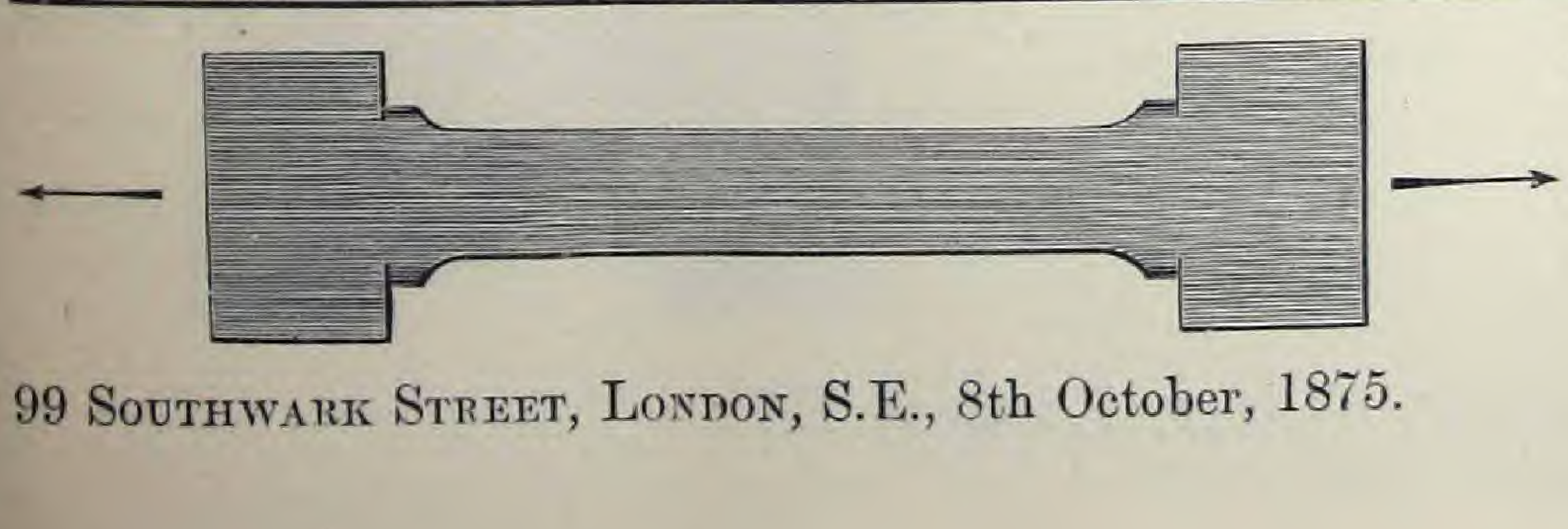
REPORT D.

ELASTIC AND ULTIMATE TENSILE STRENGTH OF WROUGHT-IRON PLATES.

HALF, AND FIVE-EIGHT INCH.

CROSSWAY.

Description.	Brand.	Number of Tests.	Thickness.	Stress. Elastic. per square inch. lbs.	tons.	Stress. Ultimate. per square inch. lbs.	tons.	Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	Extension, set. At 30,000 lbs. per square inch.	At 40,000 lbs. per square inch.	Ultimate.	Appearance of Fracture.
			inch.	lbs.	tons.	lbs.	tons.	per cent.	per cent.	lbs.	per cent.	per cent.	per cent.	
UNANNEALED.	Krupp	Mean of 3	·440	27,633	12·3	49,288	22·0	56·0	22·3	63,891	0·41	5·20	15·7	Fibrous.
	do.	Mean of 3	·530	25,266	11·2	50,307	22·4	50·2	24·9	67,285	1·34	4·62	17·7	do.
	do.	Mean of 3	·653	24,066	10·7	46,561	20·8	51·6	27·2	64,901	2·30	7·10	18·8	do.
		Mean of 9	·541	25,655	11·4	48,718	21·7	52·6	24·8	65,359	1·35	5·64	17·4	do.
	Yorkshire	Mean of 6	·388	28,083	12·5	45,369	20·2	62·4	15·5	54,952	0·46	4·82	11·1	Fibrous.
	do.	Mean of 6	·505	28,033	12·5	45,316	20·6	62·3	12·9	51,887	0·44	4·98	10·2	do.
	do.	Mean of 6	·623	27,533	12·2	46,293	20·6	59·6	15·8	55,493	0·63	5·21	12·3	do.
		Mean of 18	·505	27,883	12·4	45,659	20·3	61·4	14·7	54,110	0·51	5·00	11·2	do.
ANNEALED.	Krupp	Mean of 3	·440	24,300	10·9	45,903	20·5	52·9	22·1	59,144	2·03	7·24	16·5	Fibrous.
	do.	Mean of 3	·526	24,533	11·0	46,223	20·6	53·0	27·6	64,995	2·37	7·49	19·8	do.
	do.	Mean of 3	·646	23,600	10·5	45,007	20·1	52·4	31·5	67,584	2·71	8·60	22·8	do.
		Mean of 9	·537	24,144	10·8	45,711	20·4	52·7	27·0	63,907	2·37	7·77	19·7	do.
	Yorkshire	Mean of 6	·388	27,233	12·2	41,776	18·6	65·7	15·2	50,069	0·96	6·50	11·2	Fibrous.
	do.	Mean of 6	·501	27,250	12·1	44,164	19·6	61·8	19·2	55,485	1·01	7·53	14·8	do.
	do.	Mean of 6	·618	26,850	12·0	43,907	19·6	61·1	16·3	52,916	1·36	7·46	12·4	do.
		Mean of 18	·502	27,111	12·1	43,282	19·2	62·8	16·9	52,823	0·81	7·16	12·8	do.



Length for Extensions, 10 inches. Breadth, 2·00 inches.

99 SOUTHWARK STREET, LONDON, S.E., 8th October, 1875.

DAVID KIRKALDY.

REPORT E.

RESULTS OF EXPERIMENTS TO ASCERTAIN THE EFFECTS PRODUCED

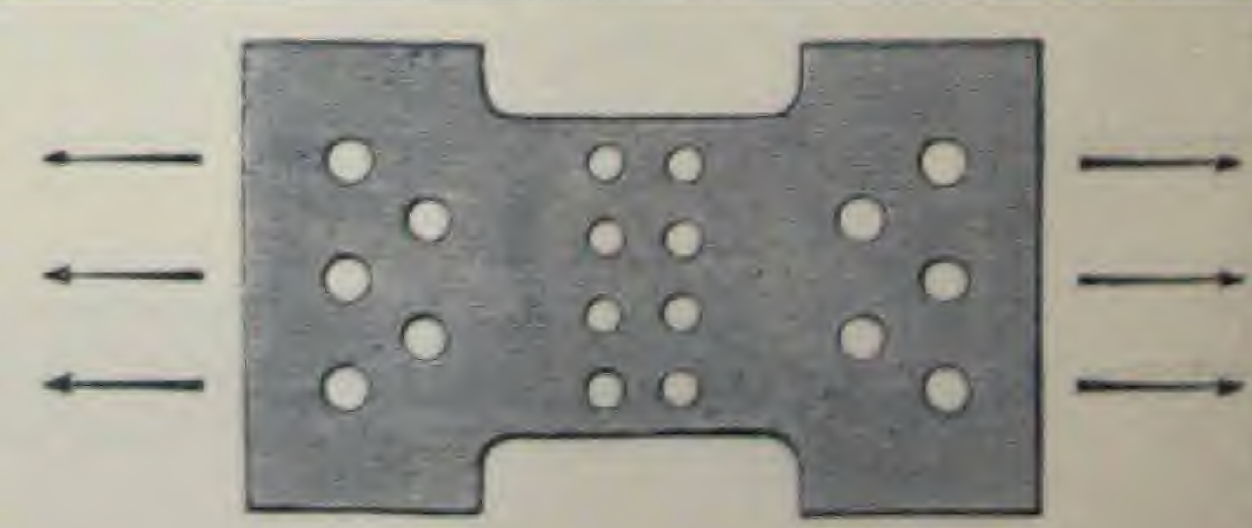
NOMINAL THICKNESSES—THREE-EIGHT,

DRILLED HOLES.

Description.	Brand.	Size of Specimen. Holes not Deducted.	Size of Specimen. Gross Area.	Test No.	Ultimate Stress. Total.	Ultimate Stress. Per square inch.	Difference or Loss. Per square inch.	Difference or Loss. Per cent.	Elongation of Holes. Fractured.	Elongation of Holes. Unfractured.	Elongation of Holes. Total.	Elongation of Holes. Total.	Appearance of Fracture.	Solid Plate. Ultimate Stress per square inch.
		inches.	sq. in.	J	lbs.	lbs.	lbs.	per cent.	inch.	inch.	inch.	per cent.		lbs.
LENGTHWAY.	Krupp	8·00 × ·44	3·52	2687	116,180	**33,005**	19,590	**37·2**	·34	·18	·52	**30·6**	Fibrous	**52,595**
	do.	8·00 × ·53	4·24	2691	141,920	**33,471**	18,309	**35·3**	·32	·19	·51	**30·0**	do.	**51,780**
	do.	8·00 × ·53	4·24	2695	138,160	**32,584**	19,861	**37·8**	·35	·19	·54	**31·7**	do.	**52,445**
	do.	8·00 × ·66	5·28	2699	162,290	**30,736**	19,199	**38·4**	·35	·17	·52	**30·6**	do.	**49,935**
				Mean		**32,449**		**37·2**				**30·7**		**51,689**
	Bowling	8·00 × ·39	3·12	2709	99,960	**32,038**	25,377	**44·2**	·23	·11	·34	**20·0**	Fibrous	**57,415**
	Taylor's	8·00 × ·39	3·12	2721	91,180	**29,224**	21,641	**42·5**	·26	·15	·41	**24·1**	do.	**50,865**
	Monkbridge	8·00 × ·37	2·96	2733	83,080	**28,067**	19,778	**41·3**	·15	·08	·23	**13·5**	do.	**47,845**
	Lowmoor	8·00 × ·50	4·00	2705	114,560	**28,640**	23,100	**44·6**	·20	·12	·32	**18·8**	do.	**51,740**
	Farnley	8·00 × ·51	4·08	2717	122,430	**30,007**	20,778	**40·9**	·21	·11	·32	**18·8**	do.	**50,785**
	Cooper & Co.	8·00 × ·52	4·16	2729	110,080	**26,461**	19,119	**42·0**	·20	·09	·29	**17·1**	do.	**45,580**
	Bowling	8·00 × ·63	5·04	2713	139,120	**27,603**	22,427	**44·8**	·23	·12	·35	**20·6**	do.	**50,030**
	Taylor's	8·00 × ·63	5·04	2725	134,970	**26,779**	22,686	**45·8**	·23	·11	·34	**20·0**	do.	**49,465**
	Monkbridge	8·00 × ·61	4·88	2737	112,310	**23,015**	16,218	**41·3**	·14	·05	·19	**11·2**	dark do. layers	**39,233**
				Mean		**27,982**		**43·1**				**18·2**		**49,217**
CROSSWAY.	Krupp	8·00 × ·44	3·52	2688	105,790	**30,053**	20,142	**40·1**	·27	·13	·40	**23·5**	Fibrous	**50,195**
	do.	8·00 × ·53	4·24	2692	132,480	**31,245**	20,890	**39·5**	·25	·14	·39	**23·0**	do.	**52,135**
	do.	8·00 × ·53	4·24	2696	127,970	**30,182**	21,263	**40·1**	·23	·12	·35	**23·6**	do.	**51,445**
	do.	8·00 × ·66	5·28	2700	163,580	**30,981**	17,294	**35·8**	·26	·15	·41	**20·1**	do.	**48,275**
				Mean		**30,165**		**38·9**				**22·8**		**50,512**
	Bowling	8·00 × ·42	3·36	2710	99,640	**29,654**	21,956	**42·5**	·18	·08	·26	**15·3**	Fibrous	**51,610**
	Taylor's	8·00 × ·39	3·12	2722	73,780	**23,647**	17,448	**42.4**	·15	·05	·20	**11·8**	do.	**41,095**
	Monkbridge	8·00 × ·38	3·04	2734	70,790	**23,286**	16,854	**42·0**	·11	·07	·18	**10·6**	do.	**40,140**
	Farnley	8·00 × ·50	4·00	2718	128,290	**32,072**	24,398	**43·2**	·19	·09	·28	**16·5**	do.	**56,470**
	Cooper & Co.	8·00 × ·53	4·24	2730	110,640	**26,094**	16,716	**39·0**	·15	·07	·22	**13·0**	dark do. layers	**42,810**
	Lowmoor	8·00 × ·50	4·00	2706	97,280	**24,320**	15,825	**39·4**	·21	·09	·30	**17·6**	dark do. layers	**40,145**
	Bowling	8·00 × ·63	5·04	2714	129,890	**25,772**	21,008	**44·9**	·18	·09	·27	**15·9**	do.	**46,780**
	Taylor's	8·00 × ·63	5·04	2726	114,130	**22,644**	18,946	**45·5**	·12	·05	·17	**10·0**	dark do. layers	**41,590**
	Monkbridge	8·00 × ·60	4·80	2738	109,980	**22,912**	20,723	**47·4**	·12	·05	·17	**10·0**	dark do. layers	**43,635**
				Mean		**25,600**		**42·8**				**13·4**		**44,919**

The Drilled Holes were made exactly the same size as those Punched : Diameter

All the Specimens



FRIED. KRUPP, Esq.,

ESSEN WORKS, RHENISH PRUSSIA ;

2 CROWN BUILDINGS, QUEEN VICTORIA STREET, LONDON, E.C.

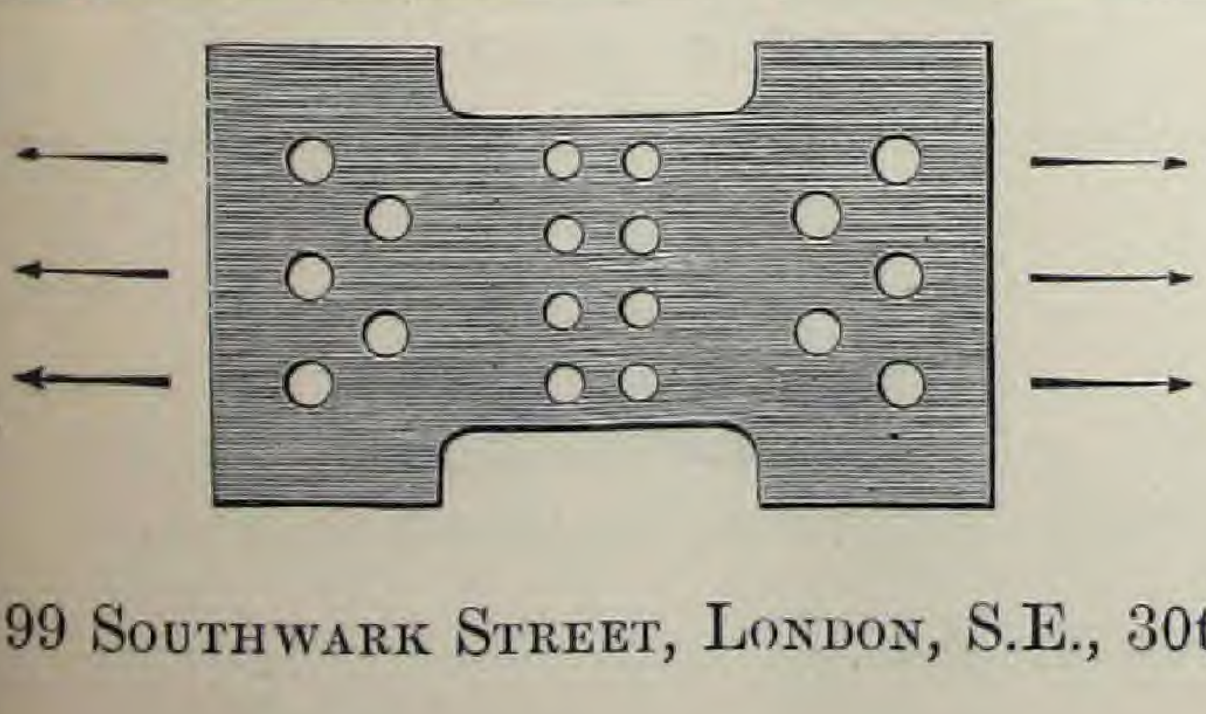
REPORT E.

BY DRILLED HOLES AND BY PUNCHED HOLES UNDER PULLING STRESS.

HALF, AND FIVE-EIGHT INCH.

PUNCHED HOLES.

Description.	Brand.	Size of Specimen. Holes not Deducted.	Size of Specimen. Gross Area.	Test No.	Ultimate Stress. Total.	Ultimate Stress. Per square inch.	Difference or Loss. Per square inch.	Difference or Loss. Per cent.	Elongation of Holes. Fractured.	Elongation of Holes. Unfractured.	Elongation of Holes. Total.	Elongation of Holes. Total.	Appearance of Fracture.	Solid Plate. Ultimate Stress per square inch.
		inches.	sq. in.	J	lbs.	lbs.	lbs.	per cent.	inch.	inch.	inch.	per cent.		lbs.
LENGTHWAY.	Krupp	8·00 × ·44	3·52	2689	98,580	**28,006**	26,534	**48·6**	·17	·05	·22	**13·0**	Fibrous	**54,540**
	do.	8·00 × ·44	3·52	2685	90,160	**25,613**	24,602	**49·0**	·19	·06	·25	**14·7**	do.	**50,215**
	do.	8·00 × ·54	4·32	2693	118,620	**27,458**	24,817	**47·4**	·18	·04	·22	**13·0**	do.	**52,275**
	do.	8·00 × ·65	5·20	2701	126,290	**24,286**	23,174	**48·8**	·19	·07	·26	**15·3**	do.	**47,046**
	do.	8·00 × ·65	5·20	2697	125,140	**24,065**	23,007	**48·8**	·16	·05	·21	**12·4**	do.	**47,070**
				Mean		**25,885**		**48·5**				**13·7**		**50,512**
	Lowmoor	8·00 × ·38	3·04	2703	67,680	**22,263**	24,787	**52·6**	·16	·03	·19	**11·2**	Fibrous	**47,050**
	Farnley	8·00 × ·40	3·20	2715	69,130	**21,603**	23,557	**52·1**	·11	·02	·13	**7·7**	do.	**45,160**
	Cooper & Co.	8·00 × ·39	3·12	2727	71,980	**23,070**	22,010	**48·8**	·10	·02	·12	**7·0**	do.	**45,080**
	Taylor's	8·00 × ·52	4·16	2723	105,490	**25,358**	22,412	**46·9**	·14	·02	·16	**9·4**	do.	**47,770**
	Bowling	8·00 × ·54	4·32	2711	100,610	**23,289**	21,021	**47·4**	·12	·02	·14	**8·2**	10 °/o do. crys.	**44,310**
	Monkbridge	8·00 × ·51	4·08	2735	96,720	**23,705**	20,510	**46·4**	·11	·01	·12	**7·0**	dark do. layers	**44,215**
	Lowmoor	8·00 × ·63	5·04	2707	120,830	**23,974**	26,431	**52·4**	·12	·02	·14	**8·2**	do.	**50,405**
	Farnley	8·00 × ·63	5·04	2719	115,610	**22,938**	24,822	**51·9**	·12	·02	·14	**8·2**	3 °/o do. crys.	**47,760**
	Cooper & Co.	8·00 × ·63	5·04	2713	118,420	**23,496**	24,274	**50·8**	·11	·02	·13	**7·7**	do.	**47,770**
				Mean		**23,299**		**50·0**				**8·3**		**46,613**
CROSSWAY.	Krupp	8·00 × ·44	3·52	2690	85,640	**24,329**	26,101	**51·7**	·15	·03	·18	**10·6**	Fibrous	**50,430**
	do.	8·00 × ·44	3·52	2686	80,180	**22,778**	24,462	**51·8**	·16	·05	·21	**12·4**	do.	**47,240**
	do.	8·00 × ·54	4·32	2694	108,090	**25,021**	22,319	**47·1**	·14	·03	·17	**10·0**	do.	**47,340**
	do.	8·00 × ·64	5·12	2698	120,280	**23,492**	23,398	**49·9**	·14	·03	·17	**10·0**	do.	**46,890**
	do.	8·00 × ·64	5·12	2702	118,720	**23,187**	23,028	**49·8**	·17	·04	·21	**12·4**	do.	**46,215**
				Mean		**23,761**		**50·0**				**11·1**		**47,623**
	Farnley	8·00 × ·41	3·28	2716	76,870	**23,436**	27,404	**53·9**	·13	·01	·14	**8·2**	Fibrous	**50,840**
	Lowmoor	8·00 × ·37	2·96	2704	64,440	**21,770**	26,690	**55·0**	·12	·01	·13	**7·7**	do.	**48,060**
	Cooper & Co.	8·00 × ·39	3·12	2728	62,490	**20,028**	20,042	**50·0**	·09	·01	·10	**5·9**	dark do. layers	**40,070**
	Taylor's	8·00 × ·53	4·24	2724	98,140	**23,046**	22,919	**50·0**	·12	·01	·13	**7·7**	do.	**45,965**
	Bowling	8·00 × ·53	4·24	2712	85,870	**20,253**	20,668	**50·5**	·11	·01	·12	**7·0**	dark do. layers	**40,920**
	Monkbridge	8·00 × ·50	4·00	2736	87,310	**21,827**	23,760	**52·1**	·11	·01	·12	**7·0**	do.	**45,590**
	Lowmoor	8·00 × ·63	5·04	2708	122,340	**24,274**	27,116	**52·8**	·11	·01	·12	**7·0**	do.	**51,390**
	Farnley	8·00 × ·63	5·04	2720	110,940	**22,011**	25,334	**53·5**	·10	·01	·11	**6·5**	do.	**47,345**
	Cooper & Co.	8·00 × ·62	4·96	2732	108,720	**21,919**	25,101	**53·4**	·09	·01	·10	**5·9**	do.	**47,020**
				Mean		**22,063**		**52·4**				**7·0**		**46,400**



·85 inch × 4 = 3·40 inches, or 42·5 per cent. of the width of the Specimen.

were Unannealed.

99 SOUTHWARK STREET, LONDON, S.E., 30th November, 1875. DAVID KIRKALDY.

REPORT F.

RESULTS OF EXPERIMENTS TO ASCERTAIN THE RESISTANCE TO

NOMINAL THICKNESSES—THREE-EIGHT,

Nominal Thicknesses.	UNANNEALED.													
	Brand.	Test No.	Thick-ness.	Stress in Pounds.—Bulged, Inches.								Ultimate.		Effects.
				25,000.	50,000.	75,000.	100,000.	125,000.	150,000.	175,000.	200,000.	Bulge.	Stress.	
THREE-EIGHT INCH.		J	inch.									inches.	lbs.	
	Krupp	1363	·44	0·81	1·34	1·75	2·12	2·58	....	....	....	3·28	139,940	Uncracked.
	do.	1553	·44	0·82	1·35	1·79	2·15	2·64	....	....	....	3·28	139,780	do.
	do.	1543	·44	0·82	1·36	1·80	2·16	2·67	....	....	....	3·26	137,560	do.
		Mean	**·440**	**0·82**	**1·35**	**1·78**	**2·14**	**2·63**	....	....	....	**3·27**	**139,093**	
	Farnley	1912	·42	0·77	1·39	1·85	2·32	....	....	....	....	3·24	116,810	Uncracked.
	Lowmoor	1852	·38	0·92	1·54	2·06	2·71	....	....	....	....	3·20	102,780	do.
	Bowling	1882	·40	0·74	1·35	1·78	2·46	....	....	....	....	3·22	114,420	Cracked.
	Monkbridge	2002	·37	0·86	1·47	1·97	2·51	....	....	....	....	2·75	110,880	Burst.
	Taylor's	1942	·39	0·80	1·42	....	....	....	....	....	....	1·84	54,720	do.
	Cooper & Co.	1972	·38	0·85	1·47	....	....	....	....	....	....	1·65	51,220	do.
		Mean	**·390**	**0·83**	**1·44**	....	....	....	....	....	....	**2·65**	**91,805**	
HALF-INCH.	Krupp	1593	·53	0·65	1·20	1·50	1·85	2·16	2·59	....	....	3·41	165,110	Uncracked.
	do.	1583	·54	0·66	1·24	1·60	1·94	2·29	2·68	....	....	3·39	164,230	do.
	do.	1573	·53	0·60	1·10	1·46	1·79	2·12	2·58	....	....	3·39	162,550	do.
		Mean	**·533**	**0·64**	**1·18**	**1·52**	**1·86**	**2·19**	**2·62**	....	....	**3·40**	**163,963**	
	Farnley	1922	·52	0·58	1·07	1·49	1·78	2·11	2·50	....	....	3·28	168,480	Uncracked.
	Taylor's	1952	·51	0·59	1·10	1·45	1·83	2·14	2·45	....	....	3·10	167,290	Burst.
	Cooper & Co.	1982	·53	0·54	1·08	1·40	1·75	2·05	2·37	....	....	2·95	168,110	do.
	Lowmoor	1862	·50	0·71	1·23	1·65	2·02	2·34	2·82	....	....	3·10	157,560	do.
	Monkbridge	2012	·51	0·62	1·14	1·52	1·88	....	....	....	....	2·16	105,720	do.
	Bowling	1892	·49	0·65	1·16	....	....	....	....	....	....	1·76	53,110	do.
		Mean	**·510**	**0·61**	**1·13**	**1·52**	**1·85**	....	....	....	....	**2·72**	**136,711**	
FIVE-EIGHT INCH.	Krupp	1603	·65	0·50	0·98	1·28	1·60	1·89	2·14	2·50	2·91	3·52	228,320	Uncracked.
	do.	1623	·65	0·50	0·98	1·32	1·66	1·95	2·23	2·57	2·98	3·50	211,820	do.
	do.	1613	·66	0·49	0·92	1·21	1·50	1·78	2·00	2·24	2·58	3·06	212,080	Burst.
		Mean	**·653**	**0·50**	**0·96**	**1·27**	**1·59**	**1·87**	**2·12**	**2·44**	**2·82**	**3·36**	**217,406**	
	Lowmoor	1872	·63	0·35	0·92	1·28	1·58	1·85	2·13	2·34	2·59	3·30	239,040	Burst.
	Bowling	1902	·62	0·44	0·98	1·37	1·68	1·94	2·21	2·48	2·87	3·08	208,140	do.
	Cooper & Co.	1992	·63	0·31	0·89	1·24	1·55	1·85	2·14	2·51	3·03	3·07	212,270	do.
	Farnley	1932	·64	0·30	0·86	1·22	1·49	1·75	2·00	2·22	....	2·72	194,740	do.
	Taylor's	1962	·63	0·34	0·95	1·30	....	....	....	....	....	1.56	85,770	do.
	Monkbridge	2022	·60	0·38	0·98	....	....	....	....	....	....	1·40	52,290	do.
		Mean	**·625**	**0·35**	**0·93**	**1·28**	....	....	....	....	....	**2·52**	**165,375**	

Disc twelve inches diameter, cut out of plates

FRIED. KRUPP, Esq.,

ESSEN WORKS, RHENISH PRUSSIA;

2 CROWN BUILDINGS, QUEEN VICTORIA STREET, LONDON, E.C.

REPORT F.

BULGING STRESS OF TWENTY-SEVEN WROUGHT-IRON PLATES.

HALF, AND FIVE-EIGHT INCH.

Nominal Thickness.	ANNEALED.													
	Brand.	Test No.	Thick-ness.	STRESS IN POUNDS.—BULGED, INCHES.								ULTIMATE.		Effects.
				25,000.	50,000.	75,000.	100,000.	125,000.	150,000.	175,000.	200,000.	Bulge.	Stress.	
		J	inch.									inches.	lbs.	
THREE-EIGHT INCH.	Krupp	1544	·44	0·81	1·37	1·80	2·21	....	....	....	....	3·28	124,910	Uncracked.
	do.	1564	·44	0·84	1·40	1·85	2·25	....	....	....	....	3·28	124,720	do.
	do.	1554	·44	0·84	1·41	1·85	2·29	....	....	....	....	3·26	122,640	do.
		Mean	**·440**	**0·83**	**1·39**	**1·83**	**2·25**	....	....	....	....	**3·27**	**124,090**	
	Farnley	1913	·42	0·90	1·50	2·00	2·60	....	....	....	....	3·24	110,840	Uncracked.
	Lowmoor	1853	·38	0·99	1·74	2·30	2·98	....	....	....	....	3·23	100,060	do.
	Bowling	1883	·40	0·93	1·51	2·00	2·62	....	....	....	....	3·22	105,110	do.
	Taylor's	1943	·39	0·92	1·57	2·06	2·65	....	....	....	....	3·21	107,960	do.
	Monkbridge	2003	·37	0·94	1·60	2·15	2·82	....	....	....	....	3·16	106,840	Cracked.
	Cooper & Co.	1953	·38	0·92	1·58	2·08	2·74	....	....	....	....	3·07	105,680	Burst.
		Mean	**·390**	**0·93**	**1·58**	**2·09**	**2·73**	....	....	....	....	**3·19**	**106,081**	
HALF-INCH.	Krupp	1584	·54	0·72	1·21	1·62	1·95	2·32	2·71	....	....	3·39	165,980	Uncracked.
	do.	1574	·53	0·75	1·24	1·67	1·99	2·44	2·85	....	....	3·38	156,920	do.
	do.	1594	·53	0·69	1·18	1·60	1·93	2·29	2·74	....	....	3·39	156,150	do.
		Mean	**·533**	**0·72**	**1·21**	**1·63**	**1 96**	**2·35**	**2·77**	....	....	**3·39**	**159,683**	
	Farnley	1923	·52	0·62	1·12	1·50	1·95	2·33	2·78	....	....	3·31	156,250	Uncracked.
	Bowling	1893	·49	0·74	1·28	1·68	2 07	2·50	....	....	....	3·28	144,080	do.
	Lowmoor	1863	·50	0·79	1·34	1·77	2·22	2·71	....	....	....	3·35	134,110	do.
	Taylor's	1953	·51	0·72	1·23	1·58	1·94	2·33	....	....	....	3·35	149,980	Cracked generally.
	Monkbridge	2013	·51	0·77	1·28	1·67	....	....	....	....	....	2·17	86,110	Burst.
	Cooper & Co.	1983	·53	0·68	1·14	1·55	....	....	....	....	....	1·86	80,050	do.
		Mean	**·510**	**0·72**	**1·23**	**1·62**	....	....	....	....	....	**2·88**	**125,096**	
FIVE-EIGHT INCH.	Krupp	1604	·65	0·55	1·06	1·41	1·75	2·08	2·32	2·66	3·18	3·50	208,350	Uncracked.
	do.	1624	65	0 59	1·10	1 46	1·78	2·15	2·43	2·84	....	3·50	190,290	do.
	do.	1614	·66	0·55	1·00	1·39	1·72	2·00	2·25	2·53	....	3·35	198,140	Burst.
		Mean	**·653**	**0 56**	**1·05**	**1·42**	**1·75**	**2·08**	**2.33**	**2·68**	....	**3·45**	**198,926**	
	Lowmoor	1873	·63	0·42	0·97	1 31	1·64	1·91	2·21	2·55	3·15	3·30	208,240	Uncracked.
	Bowling	1903	·62	0·46	0·99	1·35	1·69	1·99	2·25	2·60	3·22	3·28	206,110	do.
	Farnley	1933	·64	0·44	0·98	1·33	1·63	1·90	2·18	2·50	3·04	3·19	205,370	Cracked.
	Monkbridge	2023	·60	0·44	0·98	1·33	1·68	1·98	2·22	....	....	2·75	152,400	Burst.
	Cooper & Co.	1993	·63	0·40	0·94	1·30	1·64	1·90	....	....	....	2·38	147,230	Burst.
	Taylor's	1963	·63	0·44	0 98	1·34	1·66	....	....	....	....	2·04	119,420	Burst.
		Mean	**·625**	**0·43**	**0·97**	**1·32**	**1 65**	**1·93**	....	....	....	**2.82**	**173,128**	

and pressed into aperture ten inches diameter.

99 SOUTHWARK STREET, LONDON, S.E., 17th September, 1875. DAVID KIRKALDY.

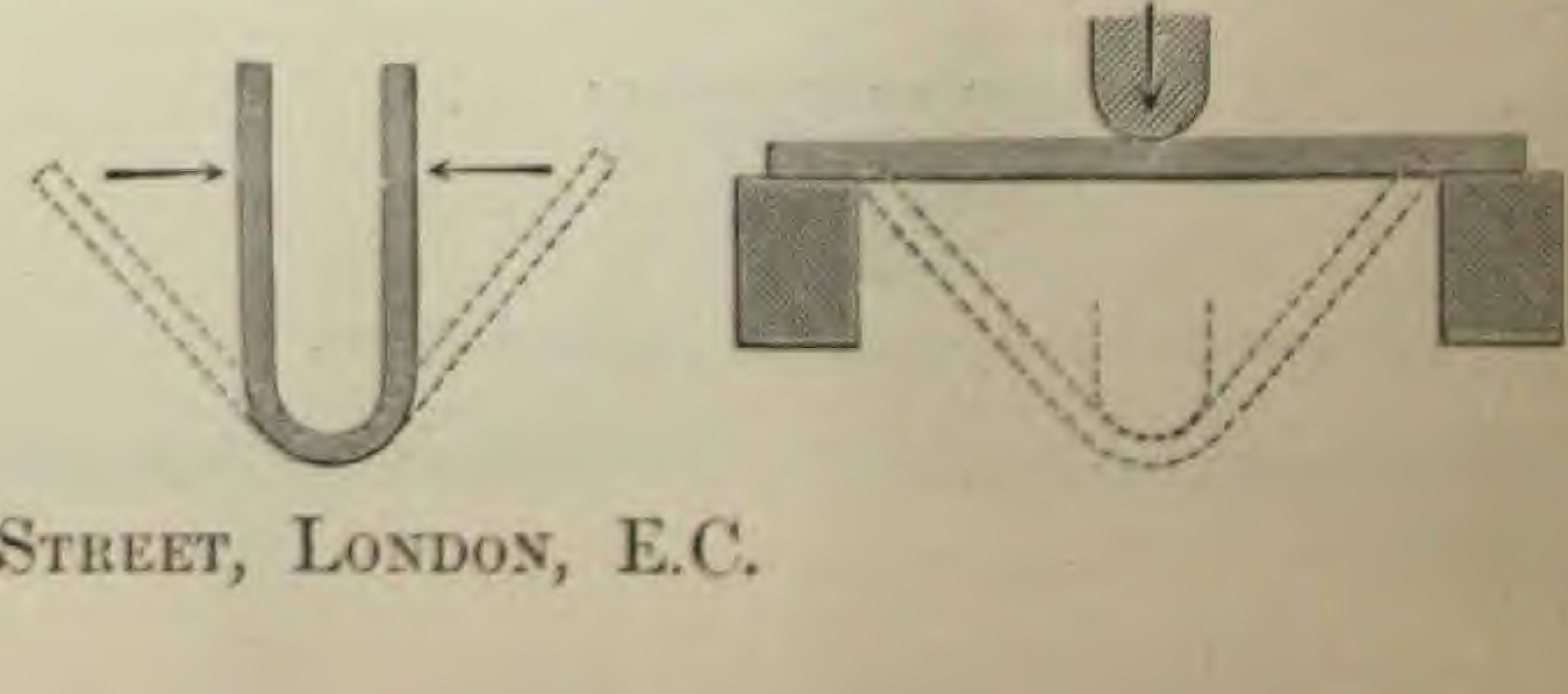
TESTING & EXPERIMENTING WORKS DAVID KIRKALDY TEST MARK LONDON.

REPORT G.

RESULTS OF EXPERIMENTS TO ASCERTAIN THE RESISTANCE TO

DISTANCE BETWEEN SUPPORTS—TEN INCHES. NOMINAL THICKNESSES—THREE-EIGHT,

Nominal Thickness.	TESTED COLD.											
	LENGTHWAY.						CROSSWAY.					
	Brand.	Test No.	Thickness.	Stress.	Angle.	Effects.	Brand.	Test No.	Thickness.	Stress.	Angle.	Effects.
		J	inch.	lbs.	degrees.			J	inch.	lbs.	degrees.	
Three-eight inch.	Krupp	1557	·46	2859	180	Uncracked.	Krupp	1558	·46	2612	180	Cracked very slightly
	do.	1567	·45	2446	180	do.	do.	1568	·45	2434	180	do. do.
	do.	1547	·44	2353	180	do.	do.	1548	·44	2289	180	Cracked.
		Mean	**·450**	**2553**	**180**			Mean	**·450**	**2445**	**180**	
	Lowmoor	1856	·37	1281	180	Uncracked.	Lowmoor	1857	·38	1367	180	Uncracked.
	Bowling	1886	·40	1632	180	Cracked slightly.	Bowling	1887	·40	1814	180	Cracked.
	Taylor's	1946	·39	1592	180	do. do.	Farnley	1917	·40	1792	180	do.
	Monkbridge	2006	·37	1381	180	do. do.	Cooper & Co.	1977	·38	1609	152	do.
	Farnley	1916	·41	1619	180	Cracked.	Taylor's	1947	·39	1758	100	do.
	Cooper & Co.	1976	·38	1809	180	do.	Monkbridge	2007	·37	1531	93	do.
		Mean	**·386**	**1552**	**180**			Mean	**·386**	**1645**	**147**	
Half-inch.	Krupp	1587	·55	3329	180	Uncracked.	Krupp	1578	·53	3003	180	Uncracked.
	do.	1577	·53	3221	180	do.	do.	1588	·54	3059	180	Cracked slightly.
	do.	1597	·53	3082	180	do.	do.	1598	·54	3022	180	Cracked.
		Mean	**·536**	**3211**	**180**			Mean	**·536**	**3061**	**180**	
	Bowling	1896	·49	2012	180	Cracked slightly.	Farnley	1927	·50	2760	180	Cracked slightly.
	Lowmoor	1866	·48	1814	180	Cracked.	Monkbridge	2017	·51	2456	168	Cracked.
	Taylor's	1956	·51	2371	180	do.	Lowmoor	1867	·50	1959	141	do.
	Farnley	1926	·51	2339	170	do.	Bowling	1877	·50	2033	137	do.
	Cooper & Co.	1986	·53	2554	160	do.	Cooper & Co.	1987	·52	2671	136	do.
	Monkbridge	2016	·51	2128	100	do.	Taylor's	1957	·52	2284	100	do.
		Mean	**·505**	**2203**	**161**			Mean	**·508**	**2360**	**143**	
Five-eight inch.	Krupp	1617	·68	4991	180	Uncracked.	Krupp	1618	·67	4959	180	Uncracked.
	do.	1607	·65	4694	180	do.	do.	1608	·65	4769	180	do.
	do.	1627	·65	4468	180	do.	do.	1628	·65	4478	180	do.
		Mean	**·660**	**4718**	**180**			Mean	**·656**	**4735**	**180**	
	Bowling	1906	·63	4105	180	Uncracked.	Lowmoor	1877	·64	4436	180	Uncracked.
	Cooper & Co.	1996	·63	4154	180	Cracked very slightly	Bowling	1907	·64	4480	180	do.
	Taylor's	1966	·63	4539	171	Cracked.	Farnley	1937	·63	4389	164	Cracked.
	Farnley	1936	·65	5432	166	do.	Taylor's	1967	·62	4292	117	do.
	Lowmoor	1876	·63	4304	158	do.	Cooper & Co.	1997	·63	4574	100	do.
	Monkbridge	2026	·60	3955	50	do.	Monkbridge	2027	·61	3516	59	do.
		Mean	**·628**	**4415**	**151**			Mean	**·628**	**4281**	**133**	



FRIED. KRUPP, ESQ.,

ESSEN WORKS, RHENISH PRUSSIA ;

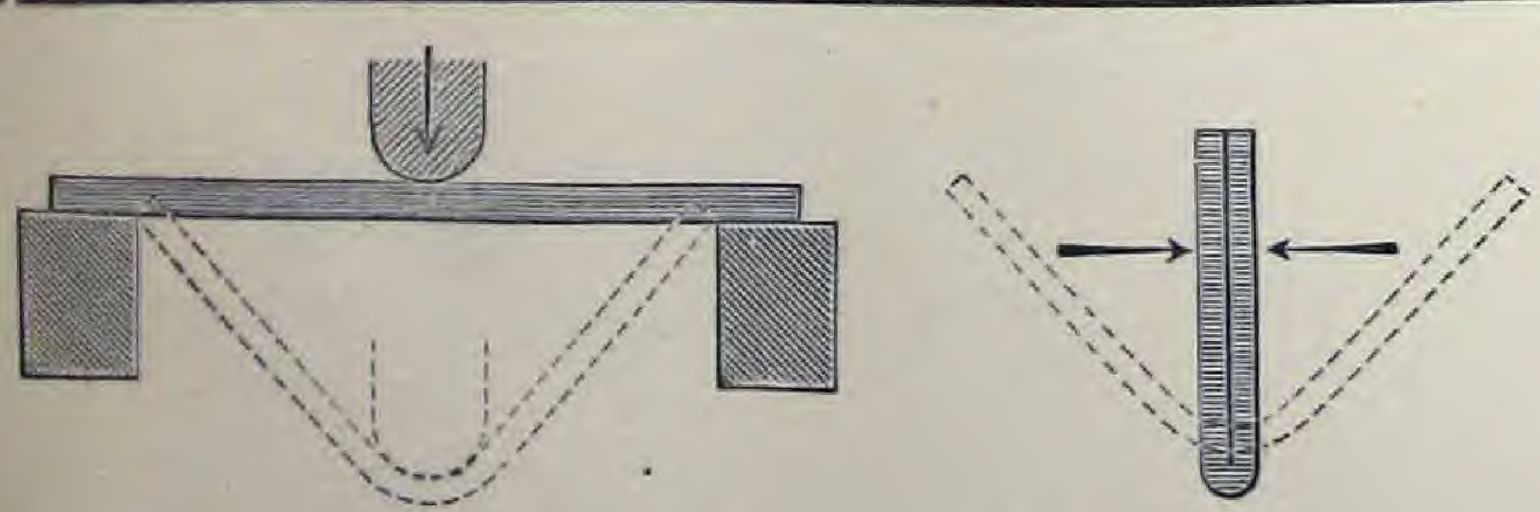
2 CROWN BUILDINGS, QUEEN VICTORIA STREET, LONDON, E.C.

REPORT G.

BENDING STRESS OF TWENTY-SEVEN WROUGHT-IRON PLATES.

HALF, AND FIVE-EIGHT INCH. DISTANCE BETWEEN SUPPORTS—TEN INCHES.

Nominal Thickness.	TESTED HOT.											
	LENGTHWAY.						CROSSWAY.					
	Brand.	Test No.	Thick-ness.	Stress.	Angle.	Effects.	Brand.	Test No.	Thick-ness.	Stress.	Angle.	Effects.
		J	inch.	lbs.	degrees.			J	inch.	lbs.	degrees.	
THREE-EIGHT INCH.	Krupp	1565	·45	580	180	Uncracked.	Krupp	1566	·45	695	180	Uncracked.
	do.	1555	·46	525	180	do.	do.	1556	·46	560	180	do.
	do.	1545	·44	490	180	do.	do.	1546	·44	560	180	do.
		Mean	**·450**	**532**	**180**			Mean	**·450**	**605**	**180**	
	Lowmoor	1854	·37	350	180	Uncracked.	Lowmoor	1855	·38	520	180	Uncracked.
	Bowling	1884	·40	565	180	do.	Farnley	1915	·40	535	180	do.
	Farnley	1914	·41	555	180	do.	Taylor's	1945	·39	510	180	do.
	Taylor's	1944	·39	450	180	do.	Bowling	1885	·40	554	180	Cracked very slightly.
	Monkbridge	2004	·37	410	180	do.	Cooper & Co.	1975	·38	550	180	Cracked.
	Cooper & Co.	1974	·38	430	180	Cracked slightly.	Monkbridge	2005	·37	501	180	do. badly.
		Mean	**·386**	**460**	**180**			Mean	**·386**	**528**	**180**	
HALF-INCH.	Krupp	1575	·53	820	180	Uncracked.	Krupp	1576	·53	740	180	Uncracked.
	do.	1595	·53	710	180	do.	do.	1596	·54	663	180	do.
	do.	1585	·55	695	180	do.	do.	1586	·54	615	180	do.
		Mean	**·536**	**742**	**180**			Mean	**·536**	**672**	**180**	
	Lowmoor	1864	·48	550	180	Uncracked.	Lowmoor	1865	·50	580	180	Uncracked.
	Bowling	1894	·49	755	180	do.	Farnley	1925	·50	682	180	do.
	Taylor's	1954	·51	633	180	do.	Monkbridge	2015	·51	520	180	do.
	Monkbridge	2014	·51	781	180	Cracked very slightly.	Taylor's	1955	·52	590	180	Cracked.
	Cooper & Co.	1984	·53	608	180	Cracked slightly.	Bowling	1895	·50	740	180	do. badly.
	Farnley	1924	·51	600	180	Cracked.	Cooper & Co.	1985	·52	620	180	do. do.
		Mean	**·505**	**654**	**180**			Mean	**·508**	**622**	**180**	
FIVE-EIGHT INCH.	Krupp	1615	·68	1080	180	Uncracked.	Krupp	1616	·67	1030	180	Uncracked.
	do.	1605	·65	1065	180	do.	do.	1606	·65	1030	180	do.
	do.	1626	·65	1003	180	do.	do.	1626	·65	1000	180	Cracked slightly.
		Mean	**·660**	**1049**	**180**			Mean	**·656**	**1020**	**180**	
	Lowmoor	1874	·63	735	180	Uncracked.	Lowmoor	1875	·64	887	180	Uncracked.
	Farnley	1934	·65	970	180	do.	Bowling	1905	·64	885	180	do.
	Cooper & Co.	1994	·63	680	180	do.	Cooper & Co.	1995	·63	910	180	do.
	Bowling	1904	·63	735	180	Cracked very slightly.	Farnley	1935	·63	895	180	Cracked slightly.
	Taylor's	1964	·63	670	180	Cracked.	Taylor's	1965	·62	770	180	Cracked.
	Monkbridge	2024	·60	685	180	Cracked very badly.	Monkbridge	2025	·61	624	180	Cracked very badly.
		Mean	**·628**	**746**	**180**			Mean	**·628**	**828**	**180**	



All planed exactly 2·5 inches wide.

99 SOUTHWARK STREET, LONDON, S.E., 17th September, 1875. DAVID KIRKALDY.